THE

GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

THE GEOLOGIST.

NOS. DCVII TO DCXVIII.

EDITED BY

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NEW SERIES. DECADE VI. VOL. II.

JANUARY—DECEMBER, 1915.

LONDON:
DULAU & CO., LTD., 37 SOHO SQUARE, W.
1915.

STEPHEN AUSTIN AND SONS, LTD.

PRINTERS, HERTFORD.

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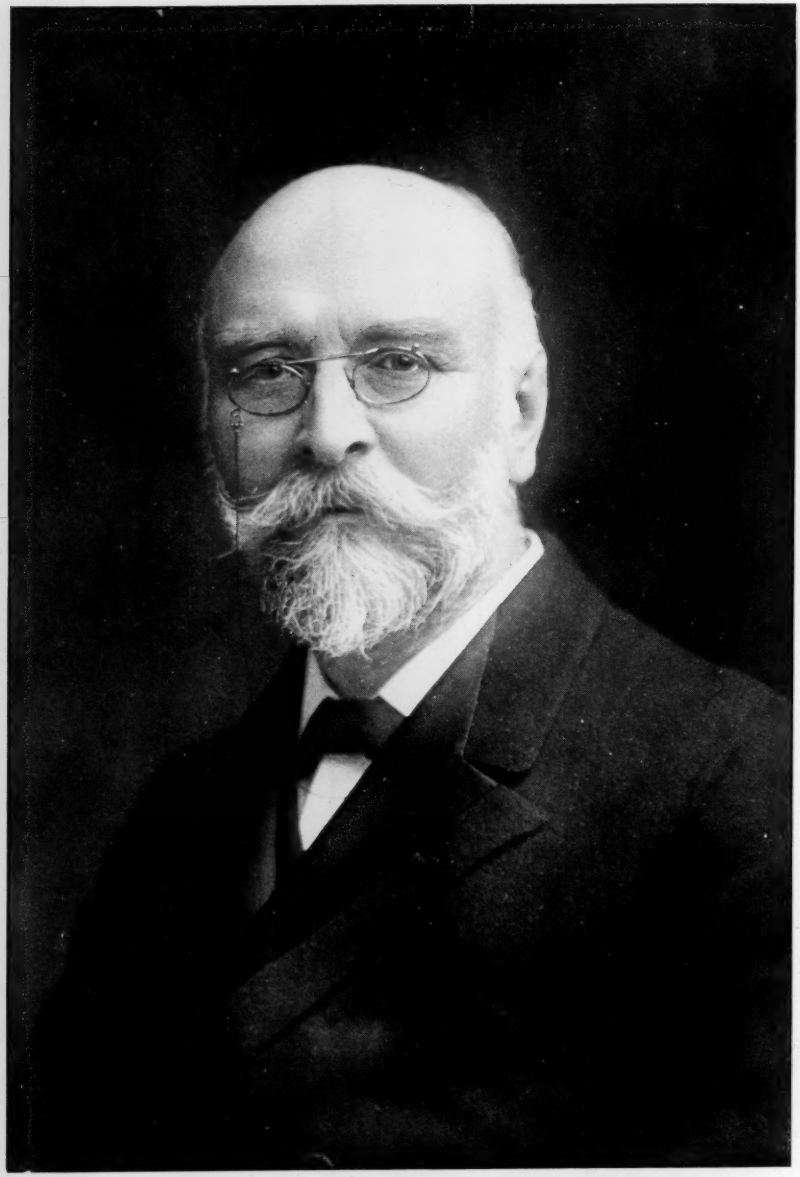

Yours Sincerely,
A. Smith Woodward

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. I.—JANUARY, 1915.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Arthur Smith Woodward, LL.D. (St. Andrews, Glasgow), F.R.S., F.L.S., F.G.S., F.Z.S., F.R.G.S., Keeper of the Department of Geology, British Museum (Natural History).

(WITH A PORTRAIT, PLATE I.)

IN presenting a portrait and offering to the readers of the Geological Magazine a brief memoir of Dr. Arthur Smith Woodward, my namesake and successor in the Geological Department of the British Museum (Natural History), I feel that no apology is needed, inasmuch as every lover of our science will be glad to possess a record of one of its leading men whom he may have met already, and known generally, but may wish for a more personal acquaintance, which this sketch is intended to furnish.

Henry Woodward.

Arthur Smith Woodward was born at Macclesfield on May 23, 1864, and began in his early school-days to take a keen interest in natural science. His special bent towards geology was fostered by the teaching of the Rev. S. G. Waters at the Macclesfield Grammar School and by the facilities the district afforded for practical work in the field. His inclination towards the study of fossils was also increased by an annual holiday at Llandudno, within reach of the Carboniferous Limestone of the Great Orme's Head. In 1880 he proceeded to the Owens College, Victoria University of Manchester, where he came under the influence of Professor Boyd Dawkins, and in 1882 he obtained by competitive examination a Second Class Assistantship in the Geological Department of the British Museum, under the Keepership of Dr. Henry Woodward.

Since 1882 Dr. Smith Woodward's scientific activities have centred entirely in the Geological Department of the British Museum, of which he became Assistant-keeper (in succession to Mr. Robert Etheridge, F.R.S.) in 1892 and Keeper (in succession to Dr. Henry Woodward, F.R.S.) in 1901. He began his career in immediate association with Mr. William Davies, who was Assistant in special charge of the fossil Vertebrata, and during the whole of his period of service he has devoted himself particularly to the study of Vertebrate Palæontology.

In 1883 the Swiney Lecturer at the British Museum was Dr. R. H. Traquair, F.R.S., who selected Fossil Fishes as his subject, and expounded the general principles to which his own exhaustive

researches had led him. Arthur Smith Woodward took elaborate notes of these lectures, and made use of them while assisting Mr. William Davies in incorporating the great Egerton and Enniskillen Collections of Fossil Fishes, which had previously been acquired by the British Museum. His curatorial work showed him that the collection of Fossil Fishes in the Museum then provided ample material for placing the study of these fossils on an entirely new basis in the light of recent discoveries. He thus began to devote his leisure to some preliminary researches, which led the Trustees of the British Museum, on the recommendation of the Keeper of Geology, to entrust to him the preparation of an exhaustive Catalogue of Fossil Fishes, which absorbed most of his energies between 1887 and 1901, and was completed in four large volumes. The work of E. D. Cope and R. H. Traquair especially laid the foundation for the new point of view from which the subject was regarded, and a large proportion of the changes in classification and interpretation of the various groups of extinct fishes proposed in the Catalogue have now been generally adopted. The first volume was noteworthy for the earliest adequate recognition of the primitive character of the Palæozoic sharks, and for the detailed description of many Mesozoic sharks, such as *Hybodus* and *Acrodus*, which had previously been known only in a vague manner. The second volume added much to our knowledge of the problematical Acanthodians and Ostracoderms, and other Palæozoic groups of so-called 'ganoids', emphasizing the importance of fin-structure in classification already recognized by Cope and Traquair. The third volume provided the first series of detailed osteological descriptions of many groups of Mesozoic 'ganoids', while the fourth volume was devoted to a critical synopsis of our knowledge of the bony fishes. During the progress of this work and subsequently Dr. Woodward published upwards of 200 small descriptive papers on various fossil fishes, besides three memoirs on the Permo-Carboniferous, Triassic, and Jurassic Fishes of New South Wales (for the Geological Survey of that country), a memoir on the Carboniferous Fishes of Victoria, Australia (for the Melbourne Museum), a Monograph of the English Chalk Fishes (for the Palæontographical Society), and a memoir on the Fossil Fishes of the Whitby Lias (for the Yorkshire Geological Society), all profusely illustrated with lithographic plates. He was also a pioneer in the description of the fossil fishes of South Africa, Brazil, Greenland, and Spitzbergen.

During the preparation of the Catalogue of Fossil Fishes, Dr. Woodward spent most of his vacations in foreign countries to examine the collections in other Museums, and became personally acquainted with those who were pursuing researches on fossil fishes abroad. He has also made similar use of his vacations in connexion with other palæontological work since the Catalogue was completed. He has thus been led to take a gradually widening interest in many departments of vertebrate palæontology, and so long ago as 1898 he prepared an elementary treatise, *Outlines of Vertebrate Palæontology for Students of Zoology*, which was published by the Cambridge University Press. Four journeys to North America in 1890, 1900, 1904, and 1909, have enabled him to follow closely the wonderful

progress made during the last twenty-five years on that continent, while two journeys to South America, in 1896 and 1907, have furnished material for many original papers. During one of his three visits to Greece, in 1901, he was officially commissioned by the Trustees of the British Museum to supervise diggings at Pikermi for fossil mammals, of which he returned with a large collection. During his vacations in Spain, in 1902 and 1905, he obtained many similar fossil mammals from Concud, in Aragon, while in 1908 and 1910, in the same country, he collected rare Jurassic fishes in the Province of Lérida, and visited the well-known painted caves near Santander.

Among Dr. Woodward's papers, other than those on fossil fishes, which resulted from these various journeys, may be specially mentioned those on the fossil reptiles and certain mammalian remains from South America, which he published with the co-operation of Dr. Francisco P. Moreno, founder of the Museum of La Plata. He described and interpreted a new Mesozoic crocodile, *Notosuchus*, from the Cretaceous of Neuquen, Patagonia, related to the crocodiles from the English Purbeck Beds; also one of the most primitive known snakes, *Dinilysia*, from the same formation. In the same district were found the remarkable skull and other remains of *Miolania argentina*, which he compared in detail with the similar extinct horned tortoises from Queensland and Lord Howe's Island, and discussed in connexion with the theory of a former antarctic continent, connecting Australia and South America. He concluded that the discovery of *Miolania* did not necessarily support the theory because it was related to a practically cosmopolitan Jurassic group of Chelonia. Among later fossils he prepared for the Zoological Society in 1899 and 1900 the first detailed account of the dried skin and associated bones of the Ground Sloth, *Grypotherium listai*, which excited so much interest and speculation when they were found in the Eberhardt cave at Last Hope Inlet, Southern Chile. His interpretation of the original piece of skin proved to be correct when the skull and other bones of the animal were subsequently discovered.

Dr. Woodward's other papers on the higher vertebrates include several accounts of British fossils. In 1905 he described Mr. Alfred Leeds' discovery of the limbs and tail of *Cetiosaurus leedsi* from the Oxford Clay of Peterborough, and showed that this Dinosaur resembled the American *Diplodocus* in having a long lash at the end of its tail. In 1910, when describing Mr. F. L. Bradley's discovery of a skull of *Megalosaurus* in the Great Oolite of Minchinhampton, he pointed out that this Dinosaur also agreed with its American representative, *Ceratosaurus*, in the possession of a horn on the nose. In 1907 he made known Mr. William Taylor's remarkable discovery of a dwarf leaping Dinosaur, *Scleromochlus taylori*, in the Triassic Sandstone of Elgin, and in the same year he published the first exhaustive description of the Triassic Rhynchocephalian, *Rhynchosaurus*, in the Report of the British Association. Among mammals, his first important paper was on the discovery of the Saiga Antelope in the Thames gravels at Twickenham in 1890. In 1891 and 1912

he also had the satisfaction of recording the first discoveries of mammalian teeth in the Wealden of Sussex by Mr. Charles Dawson and Father P. Teilhard. During the past three years he has co-operated again with Mr. Dawson in exploring the remarkable gravel deposit at Piltdown, Sussex, whence was obtained the lowest type of human skull and mandible hitherto known. His interpretation of this specimen and his reference of it to a new genus, *Eoanthropus*, were at first much criticized by certain human anatomists; but the actual discovery of the large ape-like canine tooth which he had predicted, and a renewed study of the cranial bones, have shown that his original conclusions were in the main justifiable.

Each volume of the Catalogue of Fossil Fishes was prefaced by an Introduction summarizing the results and suggesting some theoretical deductions, and during all his studies Dr. Woodward has attempted to consider their bearing on current philosophy. In 1904 he expounded his general views in an address delivered to the International Congress of Science and Arts at the St. Louis Exposition, and in 1906 he treated fossil fishes from the same standpoint in his Presidential Address to the Geologists' Association of London. In 1909 he returned to the same subject at Winnipeg, in his Presidential Address to Section C at the British Association Meeting, and in 1913 he treated it again in a popular manner in an Evening Lecture to the British Association at Birmingham. He follows the American school, founded by Cope, Hyatt, and Beecher, and is specially insistent on the truth of the doctrine of orthogenesis.

While pursuing original researches with continual energy, Dr. Woodward has not neglected the curatorial aspect of his duties, and his extensive acquaintance with fellow-workers both at home and abroad has enabled him to maintain the Geological Department of the British Museum during his Keepership in the forefront of progress. Fossils of nearly all groups from Africa, fossil lemurs from Madagascar, mammals from Asia, vertebrates of all kinds from South America and North America, mammals from the Mediterranean Islands, and Dinosaurs from Transsylvania, besides numerous important collections from the British Isles, have not only added immensely to knowledge and to the facility for making comparative studies, but have also improved the exhibited collection by substituting many complete specimens for fragments. Among the latter may be specially mentioned the dwarf *Hippopotamus* from Crete, the restored model of *Arsinoitherium* from Egypt, the skeleton of *Halitherium* from Germany, *Diprotodon* from Australia, the wonderful skeletons of *Ophthalmosaurus*, *Steneosaurus*, and *Cetiosaurus* from the Oxford Clay of Peterborough, the great fish *Portheus molossus* from the Chalk of Kansas, and the giant merostome *Pterygotus anglicus* from the Old Red Sandstone of Forfarshire. Besides these must be remembered the extensive collections of smaller fossils which have been added to the study-cabinets.

Dr. Woodward has not confined his administrative work to the British Museum, but has also taken some share in many other scientific affairs. For some years he has been a member of the Advisory

Committee on the Geological Survey appointed by the President of the Board of Education, and in 1914 he occupied the Chair. For many years he has been a member of the Boards of Studies in Zoology and Geology in the University of London. Since 1901 he has been Secretary of the Palæontographical Society and Editor of its Monographs. He has served on the Councils of the Royal Society, the British Association, the Linnean, Geological, and Zoological Societies, and the Geologists' Association. He was Vice-President of the Linnean and Zoological Societies for several years, occupied the Presidency of the Geologists' Association in 1904-6, was Secretary of the Geological Society for six years, and became President of the Geological Society in 1914. In 1889 he was awarded the Wollaston Donation Fund, and in 1896 the Lyell Medal of the Geological Society. In 1900 he received the Honorary Degree of LL.D. from the University of Glasgow, and in 1912 the same Degree from the University of St. Andrews. In 1914 he was awarded the Clarke Medal by the Royal Society of New South Wales. He has also been honoured abroad by election as Foreign Member of the Société Belge de Géologie, and as Corresponding Member of the New York Academy of Sciences and the Boston Society of Natural History.

After thirty-two years' strenuous work in the Museum Dr. Arthur Smith Woodward still retains the same untiring energy which has impelled him since his earliest years to study hard and to travel. Few scientific men can lay claim to so large a share of solid work in his own special department or to have done more individually to advance geology and palæontology, the sciences to which he has devoted his life.

His principal separate publications are :—

1899–1901. *Catalogue of the Fossil Fishes in the British Museum (Natural History)*, pts. i–iv.

1890. [With CHARLES DAVIES SHERBORN.] *A Catalogue of British Fossil Vertebrata.*

1898. *Outlines of Vertebrate Palæontology for Students of Zoology.*

1902–12. *The Fossil Fishes of the English Chalk.* Monograph of the Palæontographical Society.

He has also contributed 230 separate papers to scientific journals and proceedings of various societies at home and abroad, including upwards of fifty papers to the GEOLOGICAL MAGAZINE.

II.—STUDIES IN EDRIOASTEROIDEA. VI. *PYRGOCYSTIS* N.G.[1]

By F. A. BATHER, M.A., D.Sc., F.R.S.

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(PLATES II, III.)

MATERIALS for the study of this very distinctive genus have been accumulating for many years, and at last afford a firm basis for certain definite conclusions. Some important matters remain obscure, and the comparison of the Swedish material has been hindered by the dangerous state of the North Sea, but further delay

[1] Study V appeared in the GEOLOGICAL MAGAZINE for May, 1914.

in publication does not seem advisable. Various reasons make it convenient to deal with the species in the order of their geological age, beginning with the oldest, which is the most complete and is taken as the type-species of the genus. The new species are—

Pyrgocystis sardesoni, Lower Ordovician, Minnesota (genotype).
Pyrgocystis grayae, Upper Ordovician, Girvan.
Pyrgocystis ansticei, Middle Silurian, Shropshire.

To this genus are also referred some fossils from the Middle Silurian of Gotland which C. W. S. Aurivillius in 1892 regarded as representing seven species of the Cirripede genus *Scalpellum*. Though possibly to be reduced to only two species, they all appear to be distinct from the new species mentioned above.

The essential characters of the genus are displayed most clearly by the genotype *P. sardesoni*, to the description of which we now proceed.

A. *Pyrgocystis sardesoni* n.sp. (Plate II, Figs. 1–6.)

In March, 1901, Dr. F. W. Sardeson, of the University of Minnesota, himself a student of Palæozoic Pelmatozoa, was so generous as to send to me for study and description the rare and interesting fossils which give rise to this new genus, although he had originally intended to write on them himself. Not only this, but he has permitted me to retain the best specimen, returning him the others. Preliminary studies were made and drawings were prepared without undue delay, but various causes have up till now prevented the publication of the paper. This may seem a poor return for Dr. Sardeson's confidence, but the work at any rate has not suffered by keeping. It only remains for me to express my profound appreciation of his extraordinary kindness.

Horizon and Locality.—"The three specimens," says Dr. Sardeson, "compose all of the set, collected from the Ordovician Galena series, Stictopora bed; at St. Paul, Minnesota. The exact spot is a quarry on the west bluff of the Mississippi river, opposite the outlet at the east end of 'Pickerel Lake', as given on maps of St. Paul city."

The position of the Stictopora or, more correctly, Stictoporella bed in the Minnesota section is well known, but opinion as to the correlation with other regions has undergone much change The bed lies above the Platteville limestone and at the base of a series of shales successively termed Trenton, Black River, and Decorah, and now considered by E. O. Ulrich to represent the upper part of the Black River formation (see his "Revision of the Palæozoic Systems", Bull. Geol. Soc. Amer., vol. xxii, pl. 27; August, 1911). The Stictoporella bed comprises soft green shales and thin-bedded limestones, and is particularly rich in Polyzoa. According to R. S. Bassler (December, 1911, Bull. U.S. Nat. Mus., lxxvii, p. 38), the Decorah Shales correspond generally to the beds of Baltic Russia from the Wassalem beds (D 3) down to the Glauconite sandstone. But since the Kimmswick Limestone of Missouri (which corresponds to the top of the Decorah shales or even overlies them) contains a species of *Echinosphæra* said to be scarcely, if at all, distinguishable from

E. aurantium, it seems probable that the shales themselves correspond rather to the Orthoceras and Glauconite limestones which lie below the Echinosphæra limestone of N.W. Europe.

Material.—The three specimens may be denoted A, B, and C. A is taken as Holotype, and, having been so generously presented to the British Museum by Dr. Sardeson, is there registered as E 16,232. It was collected a few months before the other specimens, and probably came from a more exposed position, since it is partly weathered reddish-brown, whereas they are more grey. It is also rather better preserved, both as a whole and in detail, and the matrix has been more easily removed. B and C remain the property of Dr. Sardeson.

General Description.—A circular oral surface of general Edrioasteroid type, with (presumably five) straight broad subvective grooves, surmounts a cylindrical turret built up of scale-like plates imbricating from below upwards (i.e. adorally). The diameter of the turret is about two-thirds of its height. The scales bore spinules on their free borders; the oral face is obscured by longer movable spines.

Detailed Description.—The Oral Face is preserved well enough for description only in A, and here it is the perfectness of preservation that militates against description, since the greater part of the surface is covered by spines (Pl. II, Figs. 1, 2).

The diameter of the oral face is about 8 mm. Portions of four subvective grooves are visible; these are so situated that they appear to be on four adjacent rays out of a total of five; but which four they may be it is not easy to say. Two of the interradii, which are less covered with spines than the rest, are clearly neither of them the anal (posterior) interradius. Of the three remaining interradii, it is noteworthy that in one several of the spines, which seem to be a little longer, are directed towards a point at the margin of the oral face; and this suggests that the spines in question surround the anal opening. Taking this as a working hypothesis, for the present irrefutable, we find that the completely unexposed ray is the right posterior.

The Subvective Groove of the supposed anterior ray is seen to attain a width of 1·65 mm., and to be composed of a double series of plates, apparently alternating on the median line, and passing from that line outwards in a distal direction, so as to form an angle of about 140°. At the rounded distal extremity the angle becomes more acute, as the plates assume the usual fan-like arrangement. There are about five of these plates within a distance of 1 mm. An imaginary section across the whole structure shows the median line depressed, and the sides rising in a gentle convex curve, and then sinking again towards the outer edge of the ray or groove, so that this is clearly differentiated from the surrounding plates.

Of the right anterior groove, only a small portion is exposed, and this shows about five plates of one side all fenced round by spines. Each of these plates bears two tubercles, one on each brow of the convex curve, well raised above its general surface, and each depressed in its centre. It is natural to suppose that to each of these 'perforate' tubercles was articulated a spine, and this interpretation

is confirmed by the position of some of the neighbouring spines. Such tubercles were no doubt present on all the similar plates of this and of the other grooves, but of those other grooves it is only the left posterior which retains at all obvious traces of them; on the exposed portions of the remaining grooves they seem to have been less protected by preserved spines, and so to have been worn away.

The homologies of the alternating plates of the grooves are not quite certain. Presumably they must be either floor-plates or cover-plates. Since it is plain that they bore spines, they must have been, at least in part, on the exterior; and one would naturally infer that they were cover-plates. But they seem thicker and more curved and rounded than the cover-plates in Edrioasteridæ; and they might conceivably be floor-plates of which the elevated portions were exposed, leaving only the edges, especially near the median line, to be protected by small cover-plates now removed or unrecognizable. *Lebetodiscus* (Study III, December, 1908) presents such a structure, but in *L. dicksoni* the pores between the floor-plates are clear, whereas there is no trace of pores in *Pyrgocystis sardesoni*.

The Interradial Plates of the oral face are best exposed in the left anterior interradius, and to a less extent in the right anterior interradius. They merge into the imbricating plates of the turret, and the appearance is as though the turret-plates gradually became vertical and then inclined towards the oral centre. At the same time they become slightly thicker and much narrower, so that their relative thickness is considerably increased.

In part of the right anterior interradius and in the three other interradii these plates are obscured by Spines. Since these spines are of the same character as those on the grooves, it may be inferred that they were borne by similar tubercles. In the exposed interradii, however, such tubercles cannot be distinguished among the numerous irregularities of the surface. In the left posterior interradius some tubercles seem to be exposed, but it is difficult to distinguish between them and the ends of prostrate spines.

In the posterior interradius, as already stated, several spines, perhaps rather longer than most, are all directed in one way, and some of these converge to a point on the margin, to the right of the posterior interradius. A similar disposition of spines to protect the anal opening is common in spiniferous echinoderms.

The spines attained, in some cases at any rate, a length of not less than 1·3 mm. and a diameter of ·12 mm., tapering gently near the distal end. They show no sign of longitudinal striation, but are often irregularly blotched with black, which represents carbonized stroma and indicates a relatively wide-meshed stereom.

The Turret on which the oral face is supported has in specimen A (Pl. II, Fig. 4) a height of 13·2 mm., and it is uncertain whether the actual base is preserved; the cross-section is somewhat elliptical, with diameters of 10·8 mm. and 8·8 mm. In specimen B (Pl. II, Fig. 6), which seems to be still attached to a piece of rock, the height is 10 mm., and the diameters about 11 and 10 mm.; but here some of the adoral end may be missing. Specimen C (Pl. II, Fig. 3) has a height of about 11·5 mm., with diameters 10·8 and 8·2 mm.; and

here both ends may be incomplete. If allowance be made for imperfections and crushing, we may legitimately imagine a normal height of about 14 mm., and a diameter of 9·8 mm., or say two-thirds the height. The diameter seems to have been the same all the way up, and there is no indication that the turret was curved.

This turret is built up of a large number of separate thin plates, imbricating in such a way that their outer or free ends are directed upwards, i.e. towards the adoral face (Pl. II, Fig. 4). At the base of the turret these plates lie almost horizontally, but the inward dip gradually increases with each successive layer. The thickness of the turret wall is therefore at the base equal to the diameter of a plate; in A and C this amounts to at least 1·3 mm., leaving a lumen of about 7 mm. diameter (Pl. II, Fig. 3). Higher up the thickness does not decrease, but is formed rather by the combined thicknesses of the imbricating plates. The disc or body of the animal seems thus supported by the turret as a bird on its nest (Pl. II, Fig. 6). The arrangement of the imbricating plates is not very regular, but those of one tier tend to alternate with those of the tier below. In A the number of plates exposed along a single vertical line from top to bottom is about twenty-four; this means that the number of tiers is about forty-eight. About ten plates (twenty tiers) occur within 5 mm., but the plates are more widely separate above than they are below. Near the base four plates may be exposed along a vertical line of 1 mm., but this is in part due to the fact that the alternation is less regular, so that in these regions the number of tiers within the same distance would be only five or six, not eight. In the absence of a vertical section it is not possible to estimate precisely the proportion of each plate exposed, i.e. the extent of overlap; but the actual depth of the exposed portion in the upper part of the turret is about ·5 mm. It seems safe to say that not more than one-third of the plate is ever exposed.

No one of the turret plates can be entirely isolated, but in general outline those near the base may be compared to a salad-plate, with a slight concave curve next the lumen of the turret, and a stronger convex curve on the outside (Pl. II, Fig. 3). The convex curve is more pronounced in plates from the upper part of the turret. In specimen A a plate at the base has a width of about 3·75 mm. In other plates the width seems to have exceeded this, and to have about thrice the diameter. Probably the plates below are wider than those above.

Specimens A and C are laterally compressed, so that the cross-section of the turret may be said to have flat sides and rounded ends. Whether it bear any causal relation to this compression or no, it is the case that the tiers of turret-plates sink towards the base on the sides and rise towards the ends. This is visible at the very base in A.

In specimen C, which is generally of a yellowish-grey colour, the turret-plates are spotted with black in their stereom, and the spots are chiefly conspicuous on the free borders, where they seem rather regularly spaced. The meaning of these spots is suggested by A, for there, on the free borders of the turret-plates, are what appear to

be short spines, at fairly regular intervals of about ·2 mm., and each a little more than ·1 mm. long (Pl. II, Fig. 5). These spinules were, one supposes, attached to the turret-plates by strands of stroma, and it is the carbonized remains of the latter that form the black spots.

Diagnoses of the genus and of the species will follow the descriptions of the other species.

EXPLANATION OF PLATE II.

Pyrgocystis sardesoni.

FIG. 1. Specimen A. Oral face. The supposed anterior ray is uppermost; the bunch of spines supposed to be over the anal opening is near the lower margin, slightly to the right; above this on the right is exposed a part of the right anterior ray with tubercles. × 7·5 diam.

,, 2. Specimen A. Oral face. This photograph was taken before the specimen had been prepared quite so much as shown in Fig. 1. × 3 diam.

,, 3. Specimen C. Lower or distal end of turret, showing the large lumen. On the right the wall is bent inwards a little. × 3 diam.

,, 4. Specimen A. The turret from the supposed posterior side. × 3 diam.

,, 5. Specimen A. Part of the turret wall seen in Fig. 4, further enlarged to show the spinules. × 11 diam.

,, 6. Specimen B. The turret seen partly from above, showing how the centre is filled with plates. Portions of the shelly matrix still adhere to the sides of the turret, which is attached to a small fragment of rock. × 3 diam.

Figures 2, 4, and 5 are from photographs taken and worked up by Mr. Walter Moran. Figures 1, 3, and 6 are by the Author.

B. *PYRGOCYSTIS GRAYAE* n.sp. (Pl. III, Figs. 1, 2.)[1]

Material, Locality, and Horizon.—Among the echinoderms collected by Mrs. Robert Gray in the Starfish Bed of Thraive Glen, Girvan, is one, numbered by me K 8, which in general structure closely resembles Dr. Sardeson's fossil. The Starfish Bed lies near the summit of the Ordovician, as proved by the work of many geologists and palæontologists, whose remarks were summarized in my memoir on Caradocian Cystidea from Girvan (1913, Trans. R. Soc. Edin., vol. xlix, No. 6, §§ 6–8), where also the relationships of the Cystid fauna to those of other countries were discussed (§§ 559–568). Like all the fossils from the Starfish Bed described in that memoir, the present one is an imprint, and only one side is preserved.

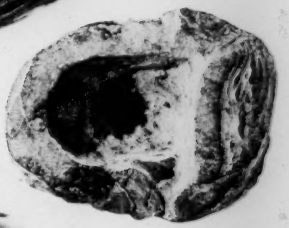
General Description.—The differences between this, for the present, unique Girvan fossil and those from St. Paul lie mainly in the greater elongation and tapering of the turret and the elevation of the oral face into a high dome.

Detailed Description.—The oral face is mounted on a kind of Cup distinct from the stem or turret. This cup is formed apparently of thin imbricating plates, serially homologous with those of the turret, but higher and more closely united. At the top they are almost square-cut. In radial position they seem to bear no definite relation to either the rays of the oral face or the vertical rows of plates in the turret. Although these plates overlap at the sides, they all appear to

[1] Plate III, containing the figures of *Pyrgocystis grayae*, will be given with the second half of the paper in the February Number.

1

2



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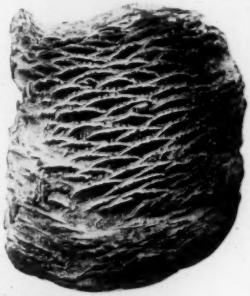

4

6

be of the same height and to reach approximately the same level. This height is about 1·3 mm. as measured from the top of the turret. The diameter of the cup at its upper margin is 4·7 mm., and below is about 3·8 mm.

The dome of the Oral Face reaches at its oral pole a height of 3·2 mm. above the cup, i.e. 4·5 mm. above the turret.

A single Subvective Groove faces the observer, and others are less clearly seen, one at each side. The groove attains a width of 1·7 mm., and is filled with alternating plates, which, as in *P. sardesoni*, may be either cover-plates or floor-plates. These plates are directed from the perradius outwards in a distal direction; the angle at which they meet is not easy to measure, but may be estimated at about 133°. The distal end of the groove is pressed against the plates of the cup, so that the arrangement of the terminal groove-plates cannot be made out. There are about three of these plates within a distance of 1 mm. A section across the groove-structures would show a broad convex curve sinking rather rapidly at each end towards the interradial area. The sutures between the groove-plates are depressed, especially along the median line of the groove, and appear rather irregular, as if they were either slightly crenelate and interlocking, or marked with alternating notches. There seems to be slight adoral imbrication of these plates.

Towards the oral pole the groove narrows considerably, and the curve of the cross-section is more markedly convex, almost angular. At the oral pole the groove-plates appear to meet those of the other rays, and there is no depression. That affords an argument for the plates being cover-plates.

The Interradial Plates of the oral face are hard to interpret. There seems to have been a single large plate within, and as it were continuing, the large overlapping plates of the cup. Then between this and the adoral groove-plates seems to be a single small plate.

The precise relation of these two interradial plates to the groove-plates is not easy to make out. There are appearances which remind one of the depressed sutures which in *Steganoblastus* continue the line of the sutures between the cover-plates. It might be inferred from this that the groove-plates, whether cover-plates or floor-plates, were in places separated from the larger interradial plates by small plates continuing the same line.

The surface of all the plates of the oral face is slightly rough, but it is not possible to say whether or no they bore spines.

The Turret is distinctly separated from the cup, at least in this unique specimen, owing to the fact that the cup-plates are more vertical, or in other words more parallel to the long axis of the animal, than are the uppermost turret-plates, and this divergence of angle results in a groove where they meet. It is, no doubt, conceivable that in other individuals, or even in this individual under other conditions of muscle-tone in life or of preservation in death, the uppermost turret-plates might be applied closely to the plates of the cup; but the distinction between cup and turret would be none the less decided, by reason of the less height of the turret-plates, or at any rate of their exposed portion. There is no reason

to suppose that the adoral region has been subjected to any such crushing or pulling as might have dragged it away from the rest. The turret then, for purposes of this description, is limited to the smaller plates, although in origin they must be of the same nature as the cup-plates.

The turret is clearly preserved for a distance of 13 mm. below the cup; beyond that distance, for 7 mm., the plates are much disturbed, but it is quite probable that the total height of the turret was 20 mm.

The diameter of the turret at its upper (proximal) end is 4·3 mm. Thence it tapers gradually, till at 13 mm. from the cup the diameter is 3·2 mm. Thus the mean diameter is about one-fifth of the height.

The turret is slightly curved.

The turret-plates imbricate adorally, and form a series of tiers. In the greater part of the turret the plates in one tier alternate quite regularly with those of the adjacent tiers. Thus the plates come to lie in definite vertical series or columns, those of one series alternating with those of the adjacent series. As the stem tapers distally the vertical series come closer together and the regular arrangement is lost. The distance between the tiers seems to become rather less as the proximal (upper) end of the turret is approached. In the upper half of the turret, i.e. in the proximal 10 mm., there are about 22 plates in vertical series, so that the usual amount of each plate exposed is about ·5 mm., a little less in the immediately proximal region, but scarcely ever more in the distal region. The number of tiers in the same distance is double, viz. 44; since there would be fewer in the distal region the total may be estimated at about 80. The number of vertical series visible in the proximal region is 5, from which a total of 10 at most may be inferred.

In spite of the regularity of tiers and columns, the wicker pattern produced is not very regular, and this is due to the ragged outline of the individual plates. Probably the adoral margin of each plate tended to form a convex curve; but the edge was thin and irregular, and has frequently been broken, so that the marginal curve is truncated.

It is quite possible that the free edge of the turret-plates supported minute spinules, but there is now no trace of such structures. At the very summit of the turret, however, lying against the outer cup-plates, are four vertical rod-like ridges; and these may represent spines.

(To be concluded in our next number.)

III.—The *Marsupites* Chalk of Brighton.

By R. M. Brydone, F.G.S.

A DESCRIPTION on modern lines of the Brighton chalk below the (old) zone of *Actinocamax quadratus* is to be found in Dr. Rowe's "Coast Sections", pt. i, p. 346.[1] The principal points that he makes are that between Ovingdean Pumping Station and Black Rock the cliffs display below the (old) zone of *A. quadratus*

[1] Proc. Geol. Assoc., vol. xvi, pt. vi.

a thickness of 58 feet of chalk, the whole of which he assigns to his zone of *Marsupites*, and further to his *Marsupites* band as *Uintacrinus* was not found in it, but he notes that *Uintacrinus* has been found on the reefs. These points have, as far as I know, stood unchallenged hitherto, but I am unable to reconcile them with my experience.

The marl band which Dr. Rowe took as the base of the old zone of *A. quadratas* (op. cit., p. 340) can be identified beyond all question as the one which in the August number of this Magazine, p. 363, I placed 15½ feet up in the subzone of *Echinocorys scutatus*, var. *depressus*. Below it I have measured the following section in which my own classification is indicated.

CHALK OF THE BRIGHTON CLIFFS BELOW THE (OLD) ZONE OF *A. QUADRATUS*.

		ft.	in.	ft.	in.
	Marl band (Dr. Rowe's base of (old) zone of *A. quadratus*).				
Zone of *O. pilula*.	8. Chalk			6	0
	Marl band.				
	7. Chalk			5	0
	Marl band.				
	6. Chalk without any crinoid brachials or plates			3	6
Zone of *Marsupites*.	5. Chalk with a number of brachials and one plate			1	0
	Very thin and rather uncertain marl band.				
	4. Chalk with crinoid brachials and curious plates			7	0
	Strong marl band.				
	3. Chalk with *Marsupites*	15	6		
	Parting with traces of marl.				
	Chalk with *Marsupites*	10	0		
	Strong marl band.				
	Chalk with *Marsupites*	8	3		
	Pair of marl bands with intervening chalk	1	6		
	Chalk with *Marsupites*	9	6		
				44	9
	Parting and weak marl seam.				
Uintacrinus band.	2. Hard chalk without crinoid remains			2	0
	Thick flint seam.				
	Chalk with one crinoid brachial	3	0		
	Marl seam.				
	1. Chalk with *Uintacrinus*	4	0		
	Marl seam.				
	Chalk with *Uintacrinus*	5	3		
	Marl seam.				
	Chalk with *Uintacrinus*		6		
				12	9
	Flint seam determining the general reef level at Black Rock.				
				82	0

	ft.	in.
Zone of *O. pilula*	14	6
,, *Marsupites*	52	9
Uintacrinus band	14	9
	82	0

It will be seen that I found 82 feet of chalk exposed in the cliff, against Dr. Rowe's measurement of 58 feet, and a considerable thickness of the *Uintacrinus* band where he found none.

The whole of Bed 1 is exposed for a distance of some 150 feet from

the last stone groin at Black Rock. The greater part of it then passes out of sight fairly quickly under the combined influence of an easterly dip and the rise of a shingle bank; but once the thick flint seam which forms its upper boundary has reached the shingle level it continues at about that level, appearing and disappearing, for quite a quarter of a mile before a further rise of the shingle hides it finally, so that there is a long exposure of the *Uintacrinus* band.

Bed 2 appears to be quite devoid of crinoid remains, and in accordance with my practice elsewhere I assign it to the *Uintacrinus* band.

Bed 3 embraces all the chalk yielding undoubted plates of *Marsupites*. It appears to be uniformly poor in fossils as compared at any rate with the *Marsupites* chalk of Hants and Kent, and especially so in the lower beds. The same progression in the plates of *Marsupites* from dwarf and smooth plates up to large and elaborately ornamented plates which appears to exist in Hants can be traced here, though not so well as in Kent, as noted by Dr. Rowe.[1] The retrogression in size, accompanied by intensification for a time in ornament ending in a sudden brief return to smoothness, which appears to take place in the upper beds in Hants, can be more or less recognized here also.

Bed 4 is the one which I specially discussed in the August number of this Magazine (pp. 361, 362), and which yields brachials and curious plates of crinoids. Brachials are distinctly more numerous here than is usual in *Marsupites*-chalk, but less numerous than is usual in *Uintacrinus*-chalk. They seem to me indistinguishable from those which accompany plates of *Marsupites* (and *Uintacrinus*), but after close examination of all the plates from this bed I am not able to assign one of them satisfactorily to *Marsupites*. They appear to be all more or less related, and I am left with a strong impression that they represent a third crinoid distinct from but generally resembling *Marsupites* and (in a stronger degree) our common species of *Uintacrinus*, and being possibly another species of the latter genus. If so it would not alter my view that the affinities of the bed are far more strongly with the zone of *Marsupites* than the subzone of *E. scutatus*, var. *depressus*, and that it should be included with the former. With it must go Bed 5, from which I have now a number of brachials and one of the peculiar plates. (In the August number of this Magazine I left this latter bed in the subzone of *E. scutatus*, var. *depressus*, thereby securing a physically definite boundary at what was then a very small sacrifice of palæontological principle.)

It is interesting to note that the *Marsupites*-chalk of Kent is crowned by a bed which appears to be more fossiliferous than this Sussex bed, but corresponds very closely in its fauna. The only noticeable point of difference is that *Hagenowia rostrata*, which has not yet occurred at this horizon in Sussex, is abundant there in Kent. This is, however, only what might be expected from the relative frequency of this fossil at lower levels in Kent as compared with Sussex, where I know of no specimen below the zone of *O. pilula* and only one in it.

[1] "Coast Sections," pt. i, p. 297.

A closely corresponding bed has been identified at Scratchells Bay, Isle of Wight, in spite of the very small area and unfavourable condition of the section (see the September number of this Magazine, p. 408); and the existence of a corresponding bed in Hants is fairly certain from the presence of one of the peculiar plates, with a brachial, at the base of my pit No. 885,[1] and from various instances of brachials unaccompanied by plates of *Marsupites* at points obviously on the border-line between the zones of *Marsupites* and *Offaster pilula* (notably my pit[2] No. 857). It is therefore likely that such a bed occurs uniformly at this horizon in South England, though the opportunities for putting this to a conclusive test away from cliff sections may be very few. There is hardly a single pit, e.g., in all Hants where the upper beds of the chalk with *Marsupites* can be positively identified and the succeeding beds are well exposed.

For a long time this Bed 4 was the lowest point to which I had traced any instance of the free-growing forms of *Retispinopora* (*R. arbusculum*, Bryd., and *R. patula*, Bryd.), or of *Lophidiaster pygmæus*, Spencer, and I had an uncomfortable feeling that this coincidence was a possible argument against including the bed in the zone of *Marsupites*; but this doubt has recently been dispersed by a specimen of *R. patula* found at the base of the zone of *Marsupites* (=*Marsupites*-band of Rowe) in Kent.

Beds 6, 7, and 8 I continue to assign to the zone of *O. pilula* and subzone of *E. scutatus*, var. *depressus*.

The zone of *Marsupites* here is almost as prone as the subzone above it to develop flint tabulars, mostly interstratified but never really persistent.

IV.—The Penmaenmawr Intrusions.

By H. C. Sargent, F.G.S.

THE subject of this paper is a group of three intrusive masses of igneous rock, possibly laccolitic in their origin, whose outcrops are situated within a radius of a mile from the village of Llanfairfechan, on the north coast of Carnarvonshire.

The most northerly and the largest of these intrusions is the well-known Penmaenmawr Mountain (1,550 feet above O.D.), and the two others lying to the south are Dinas (1,000 feet) and Carregfawr (1,167 feet).

The petrology of Penmaenmawr has already been dealt with by several writers of eminence. The rock has been described by Phillips as a quartziferous diorite;[3] by Teall as an enstatite-diorite;[4] by Harker as in part a bronzite-bearing quartz-dolerite and in part a quartz-andesite;[5] by Hatch as markfieldite;[6] by Rosenbusch as

[1] Brydone, *The Stratigraphy of the Chalk of Hants*, p. 88; London, Dulau & Co., Ltd., 1912.

[2] Op. cit., p. 86 and (under erroneous number 859) p. 92.

[3] "On the Chemical and Mineralogical Changes which have taken place in certain Eruptive Rocks of North Wales": Q.J.G.S., vol. xxxiii, pp. 423–9, 1877.

[4] *British Petrography*, 1888, p. 273.

[5] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 64.

[6] *The Petrology of the Igneous Rocks*, 7th ed., 1914, p. 369.

enstatite-diabase;[1] by Zirkel as quartz-norite;[2] and, finally, by Schaub as an augite-bearing quartz-norite![3]

Of the two southern intrusions, the only mention the writer has found is by Harker,[4] who refers to Carregfawr as "the smaller hill half-a-mile to the south, above Tai-rhedyn".[5]

The three masses are intruded into, or perhaps have broken through Lower Ordovician shales, and the accompanying Map (Fig. 1) shows their surface relations to each other. It appears probable, judging by petrological affinities, that they owe their origin to a common intercrustal reservoir.

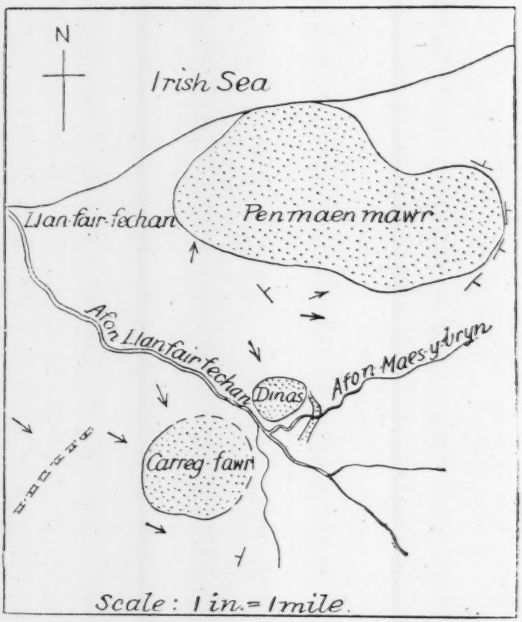

FIG. 1.—Sketch-map of Llanfairfechan District. Stippled areas, intrusive rocks; plain areas, Ordovician beds and Glacial Drift; T, strike and dip of cleavage. Arrows indicate direction of dip of imperfectly cleaved beds.

On the Geological Survey Map (Sheet 78, S.E.), published in 1852, the two southern outcrops are coloured as a single intrusion, the area of which is extended very considerably to the south and east of the limits shown on Fig. 1, so far indeed as to impinge on the lowest of the lavas of Bala age.

[1] *Mikr. Phys. d. mass. Gest.*, 2nd ed., 1887, p. 204.
[2] *Lehrbuch der Petrographie*, 2nd ed., vol. ii, p. 641, 1894.
[3] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlierenbildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., pp. 93-121, 1905.
[4] Op. cit., p. 62.
[5] A misprint on the Geological Survey Map for Ty'n-rhedyn.

After a careful examination of the ground, the writer submits that this extension of area is not supported by field-evidence. All the valleys in the area covered by the map (Fig. 1) are so choked with drift that accurate mapping of the boundaries is impossible. The streams have nowhere cut through the drift down to solid rock, except at one point where the Afon Maes-y-bryn traverses a dyke. Here the valley is suddenly constricted so as to form a narrow gorge, and it widens out again immediately below.

The drainage system appears to have been initiated in pre-Glacial times, since the valleys were carved out pre-glacially, and it is suggested that the three streams, which unite at the foot of Dinas to form the Afon Llanfairfechan, would scarcely have cut deep channels through a particularly hard igneous rock, when in other directions a choice of soft beds was readily available. Further, the rock at the foot of Dinas on the south and south-east sides of the mountain, that is to say not far from the centre of the mass as mapped by the Geological Survey, is distinctly of the marginal type referred to below, and this is sufficient to show the improbability of Dinas having originally extended to any considerable distance beyond its present limits, in the direction of Carregfawr or of the Bala lavas on the south-east. The surface of the ground in the neighbourhood of the intrusions is strongly glaciated, in places up to 1,100 feet above O.D.; and around Dinas and Carregfawr, owing to the covering of drift, it is only here and there that the Ordovician beds are exposed.

The summit of Penmaenmawr, an abrupt conical peak, appears at a distance to rise from a level table-land at the height of about 1,100 feet above O.D. On the ground it is seen that this table-land has a very uneven surface. An abrupt ridge varying from 200 to 300 feet in height above the surface of the table-land runs round the south and east sides from Clip yr Orsedd to Graig Lwyd (Fig. 2). The central portion of this eastern lobe of the outcrop is occupied by a depression filled with drift, some of which appears to be of local origin from the east.

Around Penmaenmawr the slates are frequently exposed, and a study of their behaviour towards the intrusive rock is not without interest. Contact between the two may be seen at the entrance to the most easterly of the Graig Lwyd quarries, and the sedimentary beds have here been so intensely baked to the thickness of 4 or 5 feet that it is hard to determine in the field the precise line of demarcation between them and the intrusive rock.

In the same locality, that is to say on the east of the intrusion, the slates are more perfectly cleaved than elsewhere, with nearly vertical cleavage-dip, and as shown on the Map (Fig. 1) a close parallelism is preserved between the cleavage-strike and the boundary of the igneous rock. On the southern side the sedimentary beds are imperfectly cleaved, the dip is lower than on the east, and the parallelism is lost.

Two inferences appear to be allowable from these considerations: (1) that the pressure which produced the cleavage acted here in a more or less east to west direction with the intrusive mass as

a resisting obstacle; and (2) that the intrusion is consequently older than the cleavage. The beds on the south of the intrusion could more easily yield to a pressure coming from the direction suggested, and the cleavage there would thus be less perfect. The *general* direction of the axes of disturbance that produced the cleavage over the Carnarvonshire area was S.E. to N.W., as shown by Mr. Harker.[1] Near Dinas and Carregfawr the exposures are too few and too poor to form satisfactory conclusions as to the relations of the slates to the igneous rock, though here too a similar parallelism seems to be at times approached.

Assuming, on the authority of Ramsay,[2] that the cleavage was effected "before the commencement of the deposition of the Upper Llandovery strata", it seems probable that these intrusions were contemporaneous with the great manifestations of igneous activity in Carnarvonshire, which are recognized to be of Bala age. Schaub,[3]

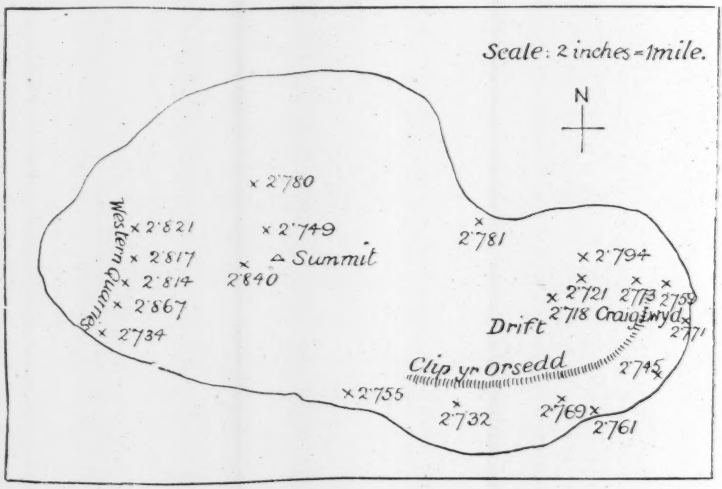

FIG. 2.—Sketch-map of Penmaenmawr.

without adducing evidence, states that Penmaenmawr is younger than Silurian and of late Palæozoic age. In the absence of evidence it is impossible to examine the reasons for this view.

The extensive quarrying operations on Penmaenmawr facilitate examination of the rock from the margin to the centre of the mass, and three distinct varieties grading into each other may be observed—(1) the marginal rock, dark-coloured, very compact, and at times somewhat cherty in appearance; this merges into (2) a fine-grained variety, rather lighter in colour, often of a bluish and sometimes of

[1] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 113.

[2] *The Geology of North Wales* (Mem. Geol. Surv. England and Wales), vol. iii, 2nd ed., p. 326, 1881. See also Harker, "Notes on the Geology of Mynydd Mawr": GEOL. MAG., Dec. III, Vol. V, pp. 221–6, 1888.

[3] Op. cit., p. 94.

a greenish tinge; this in turn passes gradually into (3) a medium-grained, light-coloured rock of speckled appearance owing to the intermixture of felspar and pyroxene phenocrysts, and the presence of a considerable amount of coarse micropegmatite. Especially towards the margin the rock is intersected by accurately parallel, platy divisional planes, in sets running in different directions and often obliterating each other. These divisional planes appear to be due to contraction on cooling.

There can be no excuse for dealing in detail with the microscopic structure of the Penmaenmawr rock, in view of what has been done by abler petrologists in this direction, but a few observations may perhaps be permitted to indicate the relationship of the different varieties to each other.[1]

The essential minerals present are, in their order of formation, bronzite; plagioclase and augite (these three occur as phenocrysts); orthoclase; quartz. Flakes of biotite also occur, as well as apatite and ilmenite as accessories. A noticeable feature of the thin sections is the progressive increase of quartz from the margin inwards, and this appears to be accompanied by decreasing basicity of the felspar phenocrysts.

The marginal rock is characterized by the presence of an andesitic ground-mass, consisting of felspar microlites with bronzite and augite in a second generation of minute crystals and grains; probably a little glass, and occasionally a small amount of quartz, some of which is doubtless of secondary origin. In places the felspar is of the allotriomorphic type. Flow-structure is frequently very marked. Among the phenocrysts, felspars are, on the whole, rather scarce, but bronzite and augite occur more frequently, the latter predominating. The bronzite is often represented here, as throughout the mass, by bastite pseudomorphs.

In the fine-grained rock the andesitic structure falls off. The ground-mass consists of felspar laths, allotriomorphic felspar, and increasing quartz; micropegmatite comes on, and in the medium-grained rock it is beautifully developed and generally forms the entire ground-mass.

Determination of the felspar phenocrysts in the marginal rock is difficult, owing to the extent to which alteration has taken place, and they are often indeterminable. The microlites of the ground-mass may be referred to oligoclase.

Thin sections prepared from the fine and medium-grained varieties allow of better determination, the felspars in the former being often quite fresh. Sections normal to the albite lamellæ show maximum extinction angles of 25° (in one instance of 30°) in the fine-grained rock. Proceeding inwards towards the centre, the extinction angles diminish to a maximum of about 20°. Schaub[2] finds extinction angles on (010) of 30°, and concludes that the species is near bytownite. In the slides examined by the writer, sections on (010) cannot often be observed, but in a slide (No. 308) prepared from the

[1] Twenty-seven thin sections of Penmaenmawr, two of Carregfawr, and five of Dinas have been examined.

[2] Op. cit., p. 96.

rock in the quarry directly under the summit such sections occur. These show extinctions of about −12°, and in one or two instances + 7° and + 10°. It may therefore be not unreasonably concluded that the plagioclase in the rock ranges from an acid labradorite near the margin to the oligoclase-andesine series in the central portion. There is no doubt that orthoclase is also present in all the varieties of the rock, but subordinate to plagioclase.

Pyroxene phenocrysts (both rhombic and monoclinic) occur in greater quantity in the fine and medium-grained rock varieties (that is to say in the inner portion and up to the centre of the mass) than in the marginal rock. The same remark holds good locally of apatite. A section from the centre (No. 308) shows larger and more abundant crystals than have been observed in any other part.

Bronzite, whether fresh or in the form of bastite, always assumes idiomorphic outlines, generally in prismatic sections. The terminations have always a ragged and frayed appearance, the result probably of resorption. Augite is generally fresher than bronzite and shows the fine basal striation noted by Teall on both pinacoids. Schaub[1] claims that this feature predominates in brownish individuals, turbid through commencing decomposition, and that it may therefore be looked upon as a secondary appearance.

The proportions of bronzite and augite are fairly equal throughout the fine and medium-grained rock.

The predominating iron-ore appears to be titaniferous. It occurs in rectangular grains and hexagonal crystals, and often shows beautiful decomposition effects. It frequently contains enclosures of apatite, and has no doubt as a rule followed that mineral in the order of crystallization. It occurs in larger crystals and in greater abundance in the inner part of the mass than at the margin.

Veins are an important feature in the structure of Penmaenmawr. They are sometimes seen to traverse the whole face of the mountain exposed by quarrying operations (the uppermost 500–600 feet), and they vary in thickness from half an inch up to 6 or 8 inches. When fresh the vein material is of a whitish or light-grey colour, but more frequently, owing to the presence of decomposition-products, it is coloured green of varying shades.

In addition to the true veins, irregular patches and streaks with similar variations of colour are common. These often display no definite boundary, but merge into the surrounding rock, and seldom extend to any great distance. Judging from their microscopic structure, referred to below, they are of the nature of segregation-patches of the more acid constituents of the rock. When much altered they have frequently a mottled appearance, green and white, owing to the presence of large flakes of quartz in addition to the green decomposition products. Grains of secondary epidote may often be observed in hand-specimens. These veins and segregation patches appear to occur in the western quarries more abundantly in the fresh condition than the green veins, and Mr. T. H. Waller[2] paid special

[1] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlierenbildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., p. 100, 1905.

[2] *Midland Naturalist*, 1885, p. 5.

attention to them there, and described their structure thirty years ago. They are called by the quarrymen 'spar'. In other parts of the mass the green veins and patches are common, and the light-coloured 'spar' is nearly absent. Schaub[1] classifies and describes these veins and patches under five heads, according to their colour and grain, but, as there is no essential difference in structure, and the different varieties can be observed in the field to merge into each other in the course of a single vein, this classification seems unnecessary.

All these veins and segregation patches afford beautiful examples of micropegmatite, which forms the greater part of the vein-material. Thin sections show the presence also of orthoclase and plagioclase crystals (the latter in subordinate quantity), augite, biotite, apatite, ilmenite, and secondary epidote. There is also frequently present a colourless mineral, showing radiating structure and with high indices of refraction and double refraction, which Schaub determines as prehnite, and considers to be an alteration-product of plagioclase. On the authority of Brauns he explains its presence as follows:—[2]

Plagioclase, an isomorphous mixture of Ab and An molecules, is in respect of the Ab molecules subject to alteration into kaolin ($2\,H_2O\,.\,Al_2O_3\,.\,2\,SiO_2$).

$$Na_2O.Al_2O_3.6\,SiO_2+2\,H_2O=Na_2O+4\,SiO_2+2\,H_2O.Al_2O_3.2\,SiO_2.$$

Two An molecules, with the addition of water and the SiO_2 liberated from the Ab molecule, give prehnite ($H_2O\,.\,2\,CaO\,.\,Al_2O_3\,.\,3\,SiO_2$) and kaolin.

$$2\,(CaO\,.\,Al_2O_3\,.\,2\,SiO_2)+3\,H_2O+SiO_2=H_2O\,.\,2\,CaO\,.\,Al_2O_3\,.\,3\,SiO_2+2\,H_2O\,.\,Al_2O_3\,.\,2\,SiO_2.$$

In the green veins the orthoclase of the intergrowth, and generally also that of the phenocrysts, is altered to an aggregate of chlorite. Not infrequently the phenocrysts show only a border of chlorite, the interior being altered mainly to epidote. The plagioclase crystals in the veins are often less altered than the orthoclase. They show very fine lamellar twinning on the albite law, with low extinction angles, and may be referred to oligoclase. Bronzite appears to be absent from the veins and segregation-patches. Augite is subordinate in quantity. It rarely shows crystal outlines, and is generally represented by secondary hornblende. Biotite occurs very locally and only in shapeless grains. A little apatite also occurs locally, generally in long needles. Ilmenite is abundant and often shows good crystal outlines, with much production of leucoxene. It also alters occasionally into a semi-translucent, dark-brown substance, slightly doubly refracting, and giving indistinct biaxial effects in convergent light.

The significance of these veins has been pointed out by both Waller and Teall. To quote the latter:[3] "They are composed of the mother-liquor left after the separation of the more basic compounds." On this view, it may be assumed in the case of the true veins that fissures and crevices, the result of contraction of the cooling mass,

[1] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlierenbildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., pp. 111 et seq., 1905.

[2] Op. cit., p. 115. [3] Op. cit., p. 275.

were filled from below by a magma depleted of a considerable portion of its more basic elements. In the case of the segregation-patches, we have apparently a local residuum of the more acid constituents separated in the course of the consolidation of the enveloping rock. On the other hand, Rosenbusch suggests that Schaub's analyses of these veins indicate that they are the effect of decomposition rather than differentiation-products.[1] Four analyses are quoted below.

On Fig. 2, an enlarged sketch-map of Penmaenmawr, the precise spots at which specimens for thin sections were collected are shown, and the specific gravity of each specimen is given.

It might reasonably be expected that decreasing density from margin to centre would follow the progressive acidity in the same direction noted above, but, as will be seen from the figures, the reverse is on the whole the case. The rock appears to attain its greatest density in the neighbourhood of the summit and in the western quarries directly below. This is no doubt the result of greater concentration locally of the heavier minerals, especially ilmenite, bronzite, and augite, as observed above.

Alteration of minerals is of course an important factor as affecting their density, which is generally lowered thereby, through the removal in solution of heavy constituents. The variations in the density of specimens collected within a short distance of each other near the summit and in the Graig Lwyd quarries are probably the result of more or less intensive local alteration, coupled with capricious distribution of some of the heavier minerals.

The compact marginal rock shows a tolerably uniform density ranging from 2·732 to 2·771. Here too the extensive alteration noted above has probably had a lowering effect, and, as already noted, iron-ores and ferro-magnesian minerals are less abundant than in other parts of the mass. Not always, however, is alteration attended by diminution of density. In the case of the green veins where the felspars are chloritized, the specific gravity generally exceeds 2·90. Seeing that the rock before alteration consisted mainly of quartz and felspar, it is evident that there has here been an increase of density, resulting perhaps from derived iron and magnesia, which it is suggested have been liberated from the bronzite of the enclosing rock on its alteration into bastite.

Phillips, in his paper referred to above, gives analyses (of which three are quoted below) of four specimens from different parts of the mass, as evidence of progressive metamorphism by surface agencies. The present writer finds it difficult to accept his conclusions in their entirety. Phillips' "practically unaltered rock", which gave the results shown in his No. i analysis, is described as fine-grained and distinctly green in colour. It was evidently very near to the marginal rock with andesitic structure, since it was collected from

[1] "Die von Schaub mitgeteilten Analysen dieser Schlieren lassen sich kaum als Differentiationsprodukte verstehen, sondern deuten eher auf Zersetzungserscheinungen": *Mikr. Phys.*, 4th ed., vol. ii, p. 1258, 1908. [The analyses of the veins, communicated by Schaub, can scarcely be considered differentiation products, but rather suggest that they are the effects of decomposition.—Ed.]

the most westerly quarry and showed under the microscope a ground-mass of felspar microlites with very little free quartz. The distinctly green colour is perhaps enough in itself to make this specimen suspect, and it has been shown above that alteration has made considerable progress in the marginal rock, especially in regard to the felspar and bronzite phenocrysts. Further, the high specific gravity (2·94) of this specimen suggests the possibility of alteration of the sort referred to in the case of the green veins.

The progressive increase of SiO_2 in Phillips' analyses appears to be attributed by him, in some degree at any rate, to its liberation from felspar as a result of alteration. In addition to his analyses, two others are given below which Mr. Eric Sinkinson, of the Imperial College of Science and Technology, has kindly prepared for this paper. Of these, one is of the compact rock on the margin of the intrusion, and the other is of the medium-grained rock from the centre. Alteration of some, at any rate, of the constituent minerals has without doubt affected the result of all these analyses, and probably none of them can be taken to represent the original unaltered rock.

The five analyses are arranged in progressive order to show the composition from margin to centre, and Phillips' analyses are also given in his order of progressive alteration. The writer submits that, looking at the analyses as a whole, they serve to confirm the microscopic examination, and that, instead of progressive alteration, they show that consolidation has to some extent followed the normal course of increasing acidity from the margin inwards. The proportion of secondary quartz seen in thin sections, which may have been liberated from the felspars, etc., is so small as not to interfere with this view.

The varying amounts of lime and magnesia may probably, to a considerable extent, be attributed to a capricious distribution of plagioclase and pyroxene, which is very noticeable in thin sections. This suggestion is perhaps confirmed by the low specific gravity of the specimens which the analyses show to be poorest in these constituents. On the other hand, it is evident that the large percentage of combined water in Phillips' No. iv analysis points to considerable alteration and the formation of hydrated silicates.

It is, however, clear from what has been said above that, in spite of the progressive acidity referred to, the course of 'fractional crystallization' has not proceeded normally. Bronzite, always the earliest formed and the most basic of the phenocrysts, is more abundant at the close of consolidation than at its commencement. The same observation holds good of both augite and apatite. It is perhaps safest not to include the iron-ores in this consideration, as they probably separate out at any stage of the process, but the rock is essentially more basic in the interior than at the margin.

Leaving, however, the consideration of this problem for the moment, it now remains to deal with the two small southern intrusions forming the mountains of Dinas and Carregfawr. No quarrying operations have been undertaken on Dinas, and it is therefore only the surface rock that can be examined and described.

The greater part of the rock as seen in the field, including that on the summit, is similar in all respects to the compact marginal rock of Penmaenmawr, and, like the latter, often breaks with conchoidal fracture. Round the base of the mountain, on the south and south-east sides, the rock is slightly less compact and is precisely similar in appearance to the transition-rock between the compact and fine-grained varieties of Penmaenmawr. It may therefore be reasonably inferred that only a limited amount of erosion has been effected by the stream sweeping round the base. On Carregfawr also only surface rock is available for examination, and it is all, including that of the summit, of the same compact type as the marginal rock of Penmaenmawr. Here, too, the platy divisional planes noticed above in the case of Penmaenmawr are well developed.

One description of thin sections will serve for the microscopic structure of the two intrusions. The minerals present are felspar, augite, and quartz, with apatite and iron-ores as accessories. Bronzite appears to be entirely absent. Felspar and augite occur as phenocrysts. The rock is much decomposed and the felspars are almost indeterminable. They appear, however, always to extinguish straight or with low angles. Augite rarely presents idiomorphic contours, but occurs mostly in the form of rounded grains. Occasionally cross-sections occur showing good outlines, the prism and pinacoid faces being equally developed. The fine basal striation on the pinacoids, noted in the case of Penmaenmawr, also occurs here. The ground-mass consists of felspar-laths, but more often of allotriomorphic felspar, and interstitial quartz. Sometimes the quartz occurs in large sheets, but never with crystal outlines. Minute grains of augite are also present in the ground-mass. Ilmenite appears to be the principal, if not the only iron-ore. It occurs in minute grains and crystals of rectangular and hexagonal outline. Generally speaking, the microscopic structure of these rocks is very similar to that of the compact marginal rock of Penmaenmawr, but quartz is on the whole more abundant here, and rhombic pyroxene as noted above is absent. The structure of the ground-mass in places may be termed sub-granophyric.

The question of the name that should be applied to the rock of which these three intrusions are composed appears to be a matter of some difficulty. The writer would naturally defer to the opinion of any one of the eminent geologists named above, of whom each has in the case of Penmaenmawr bestowed upon it a designation of his own. As it is clearly impossible to defer to them all, an independent suggestion may be permitted. It seems desirable that, if possible, the name adopted should connote not only internal structure but also mode of occurrence. Seeing that we are dealing with masses of hypabyssal habit, it will be well to discard any name properly applicable to a rock of plutonic or extrusive origin. If this be granted, we may at once rule out 'diorite', 'norite', and 'andesite'. 'Diabase' would doubtless be dismissed *sans phrase* by all British geologists nowadays.

In view of the determination of the felspars given above, and the analyses quoted below, the name 'dolerite' appears to imply a more

basic rock than the one in question, which is clearly of intermediate character. Moreover, the structure is hardly doleritic, seeing that there is nothing in the rock in the nature of the ophitic habit, or to show that the felspars have on the whole crystallized out before the augite. In view of the wide structural variations shown to exist in the Penmaenmawr mass, 'markfieldite' does not seem a very suitable name for a rock, none of whose varieties agrees closely with the type-occurrence, and some of which depart from it widely.

The decks being thus cleared, it remains to suggest that since the Penmaenmawr rock is porphyritic in structure, hypabyssal in occurrence, and intermediate in composition, its essential constituents being bronzite, augite, and soda-lime felspars, it may be safely classed with the porphyrites, as has been done by Hatch,[1] and there can be no more appropriate name for it than bronzite-porphyrite.[2]

The different varieties can be distinguished by suitable prefixes. Thus at the margin we have an andesitic-bronzite-porphyrite; further inwards a quartz-bronzite porphyrite; and in the most acid variety, which clearly grades in the direction of the true granophyres, a granophyric-bronzite-porphyrite. The rock of Dinas and Carregfawr, so far as existing exposures enable us to examine it, may be termed a quartz-porphyrite.

It is to be observed, however, that in the case of Penmaenmawr a laccolitic origin is by no means established. The flow-arrangement, so pronounced in the andesitic type of the margin, and the phenomena noticed above which have attended the consolidation of the mass, are features which appear to be opposed to the view of an interbedded injection of homogeneous magma. The simultaneous injection of bodies of magma of heterogeneous composition can hardly be invoked to explain the latter feature, since the variation from margin to centre appears to be a continuous one, and there is nothing in the shape of banding or the streaked structure that would be present if such were the case.

The writer has already been perhaps somewhat too fertile in suggestions, but he will venture on one more before closing this paper.

Harker, in the fascinating chapter entitled "Review of Vulcanicity in Caernarvonshire", in the work referred to above, has pointed out the probability that volcanic action in this region manifested itself in Bala times as a result of the pressure from the south-east; "the fluid lava . . . being lifted by the pressure into the sphere of action

[1] *Text-book of Petrology*, 5th ed., p. 219, 1909.

[2] Since the above was written the writer finds that Rosenbusch was latterly inclined to take the same view. "Doch kann man es wegen seiner ausgesprochen porphyrischen Struktur nicht wohl zu den Noriten stellen. Ob man es nicht besser seiner chemischen Konstitution nach, zumal wegen seines hohen Gehaltes au Kieselsäure zu den Enstatit-porphyriten stellen sollte, darüber liesse sich streiten" (*Mikr. Phys.*, 4th ed., vol. ii, p. 1258, 1908). [One cannot, in consequence of its pronounced porphyritic structure, very well class it with norites. It is an open question if it would not be better, having regard to its chemical composition, and particularly considering the amount of silica it contains, to class it with the enstatite-porphyrites.—ED.]

of volcanic agency, or perhaps actually squeezed out by this crust-pressure itself."[1]

If we may assume that the three intrusions discussed in this paper are the plugs of a small group of extinct volcanoes, the observed phenomena would seem capable of ready explanation.

The lighter and more acid portion of the contents of the inter-crustal reservoir would be first drained off, and it is perhaps represented by the rhyolites of the Dwygyfylchi and Y Drosgl series which are distributed round the suggested vents as a centre.[2]

If we assign Penmaenmawr and its neighbouring intrusions as the source of these lavas, the necessity of postulating an earlier volcano in the vicinity of Y Foel Fras, which "has been destroyed by a later and more extensive invasion of the igneous magma",[3] seems to be removed. Later on, the eastern lobe of the Penmaenmawr outcrop, including the Clip yr Orsedd and Graig Lwyd ridge, would be extruded, and this rock would thus constitute a true andesite, from which indeed it is indistinguishable in microscopic structure. It may perhaps be thus paralleled with the andesites of Y Foel Fras. Finally, but not necessarily at the same stage in each case, the vents would be choked with the rock forming the higher part of Penmaenmawr and the two smaller intrusions on the south.

It may be remarked that the boss-like forms of the outcrops, and the behaviour of the surrounding slates, suggest that the three masses rise more or less perpendicularly from below; and finally, they are aligned with the extinct vents lying to the south-west, Y Foel Fras and Mynydd Mawr, on the strike of the axes of disturbance that produced the folding and the cleavage of the district, and led to the outpouring of the lavas of Bala age.

PS.—It will be noted that, in the analyses of the rock, soda is always in excess of potash, thus confirming the result of the microscopic examination that orthoclase is subordinate to plagioclase. In the grey veins, which, as stated above, are comparatively fresh and in which plagioclase is subordinate, potash is in excess. In the green veins, where alteration of the felspars has proceeded much further than in the grey veins, the alkalies are strikingly reduced in quantity.

The high Ca O content of the veins, as compared with the rock, is noteworthy. In the former case it appears that the lime has not been removed by alteration-processes (as has probably happened in the case of the rock), but has gone to the formation of prehnite, and its percentage is relatively increased owing to the removal of alkalies, etc.

It is to be observed that Schaub shows no combined H_2O in his analysis of the green vein (No. iv), notwithstanding the presence of hydrated silicates (prehnite and chlorite). Clearly the percentages of this analysis are relatively increased by the omission.

[1] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 120.
[2] The writer hopes to describe this series of lavas in detail in a future paper.
[3] Harker, op. cit., p. 124.

ANALYSES OF PENMAENMAWR ROCK.

	I.	II.	III.	IV.	V.
SiO_2	56·13	58·45	60·31	61·75	63·75
Al_2O_3	27·44	17·08	18·99	18·88	14·94
Fe_2O_3	1·39	0·76	1·07	0·52	3·54
FeO	1·96	4·61	4·31	3·52	1·67
MnO	—	trace	trace	trace	—
CaO	4·94	7·60	5·81	3·54	5·12
MgO	1·93	5·15	0·83	1·90	5·95
K_2O	0·98	1·02	1·67	1·24	0·98
Na_2O	1·56	4·25	4·55	3·67	2·30
P_2O_5	—	trace	trace	trace	—
FeS_2	—	—	—	0·09	—
H_2O (hyg.)	·06	0·12	0·40	trace	—
H_2O (comb.)	3·66	0·95	1·82	4·46	2·52
	100·05	99·99	99·76	99·57	100·77
Sp. gr.	2·771	2·94	2·79	2·79	2·840

I. Compact marginal rock (Graig Lwyd Quarry). Analysis by E. Sinkinson.
II. J. A. Phillips' No. i analysis. Fine-grained green rock from most westerly quarry. (Q.J.G.S., vol. xxiii, p. 424, 1877.)
III. J. A. Phillips' No. ii analysis. Moderately fine-grained rock from most easterly quarry. Coarser than his No. i rock and less green. (Ibid.)
IV. J. A. Phillips' No. iv analysis. Rock from second quarry from west; resembles his No. ii rock, but is coarser in grain and felspar more extensively altered. (Ibid.)
V. Medium-grained rock from the centre of the mass. Analysis by E. Sinkinson.

Note.—Phillips' No. iii analysis was of rock of about the same degree of fineness as his No. i rock, and it had "evidently undergone more extensive alteration". Its content of SiO_2 was 62·24 per cent. (Op. cit., p. 425.)

ANALYSES OF PENMAENMAWR VEINS.

	I.	II.	III.	IV.
SiO_2	62·70	65·1	69·53	70·42
Al_2O_3	15·95	12·9	12·98	12·69
Fe_2O_3	1·88	2·0	1·27	1·72
FeO	2·65	4·7	1·99	2·10
MnO	—	trace	trace	trace
CaO	8·46	4·7	8·87	11·34
MgO	3·11	2·8	1·02	0·89
K_2O	0·47	3·9	1·85	trace
Na_2O	0·57	2·8	0·94	0·23
H_2O (comb.)	4·00	—	—	—
H_2O	—	1·9	—	—
Ignition	—	—	1·29	—
	99·79	100·8	99·74	99·39
Sp. gr.	2·940	2·72	2·687	2·945

I. Green vein from near centre. Analysis by E. Sinkinson.
II. T. H. Waller. Grey vein from western quarries. (*Midland Naturalist*, 1885, p. 5.)
III. L. Schaub. Grey vein. (*Neues Jahrbuch für Mineralogie*, etc., 1905, Abh. p. 113.)
IV. L. Schaub. Green vein. (Ibid., p. 118.)

V.—The Work of Professor Lacroix on the Laterites of French Guinea.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S., Geological Survey of India.

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I. Introduction.

A SHORT while ago I received from Professor A. Lacroix a copy of a recently published memoir on the laterites of French Guinea, accompanied by the request that I should, if possible, give an account of this work in the Geological Magazine, "puisque c'est là qu'ont paru les articles les plus importants sur cette question." I have undertaken this task with the greater pleasure because Professor Lacroix was so good as to show me, when I was passing through Paris recently, both his hand-specimens and his microscopic preparations of these rocks, and because the memoir in question seems to me to be one of the most important and thorough pieces of work on laterite published since Max Bauer's account of the laterite of the Seychelles.[1] Although Professor Lacroix' memoir deals professedly with French Guinea only, yet it is probable that many of the conclusions will be found to apply to other regions, and on this account, and because the series in which the memoir appears will probably not be readily accessible to all, I have thought it desirable to expound it at some length.

The full title of the memoir is "Les latérites de la Guinée et les produits d'altération qui leur sont associés", the medium of publication being the *Nouvelles Archives du Musée*, sér. v, tom. v, pp. 255–356, with pls. x–xvii, 1914. It is the fruit of a visit to West Africa by the author in the winter of 1912–13, when he was able not only to explore in detail the Archipelago of Los, but also to traverse many parts of French Guinea. From Konakri on the coast to the Niger

[1] *Neues Jahrb. für Min.*, etc., ii, pp. 192–219, 1898.

Professor Lacroix followed the railway line, which provided many valuable sections ; then, after examining the cuttings of a line under construction from Kouroussa to Kankan, he descended the Niger to Siguiri, which is about 360 miles in a straight line from Konakri. After touring in Bouré, a part of the ancient Sudan, he returned to Siguiri by an affluent to the left bank of the Niger, the Tinkisso, returning thence to Konakri. Professor Lacroix has also made a field study of the laterites of Madagascar on the opposite side of Africa, but he is compelled by lack of space to defer to a subsequent volume of the *Archives* an account of his work in that island.

The importance of this work on Guinea results in the first place from the fact that the author was able to examine in the field a large number of fresh sections, many of which showed the complete passage from the underlying fresh rock, through the various stages of lateritization, to the surface crust or *cuirasse*; that secondly he collected his specimens with judgment from known points in the sections, and thirdly that he has supplemented the chemical analyses (due to M. Boiteau) by careful microscopical studies of the mineralogical composition. He is thus able to trace the successive stages of change in both chemical and mineralogical composition from underlying fresh rock to surface crust. His results are rendered the more convincing by a splendid series of plates showing the field relationships (twelve photos), the aspect in hand-specimens (twelve photos), and, finally, the microscopic appearance (twenty-four photos).

II. Nomenclature.

In an introductory chapter Professor Lacroix discusses the nomenclature of the subject. After referring to Buchanan's original definition and the demonstration of Van Bemmelen [1] and Max Bauer [2] that laterites rich in hydrates sometimes contain a considerable quantity of silicates of aluminium, without differing in any way in external characters from laterites quite free from silicates,[3] he concludes (p. 258)—

"Enfin, de véritables argiles, de vrais kaolins, abondent sous les tropiques, et ils sont, eux aussi, souvent colorés en rouge par de l'oxyde de fer."

The author then arrives at the following definition of laterite (p. 259):—

"Les produits de décomposition de toutes les roches, silicatées alumineuses caractérisés, au point de vue chimique, par la prédominance de hydroxydes d'aluminium et de fer, avec généralement de l'oxyde de titane, après élimination plus ou moins complète des autres éléments de la roche fraîche : alcalis, chaux, magnésie et silice" :

this definition agreeing with that now generally accepted.

[1] *Arch. néerl. Sc. exactes et nat.*, xv, pp. 294–305, 1910.

[2] *Neues Jahrb. Min. u. Pet.*, Festband, 1907, pp. 33–90.

[3] For the frequent difficulty or impossibility of distinguishing laterites from some clays in the absence of chemical examination, see Sir T. H. H. Holland, in the discussion on Mr. J. M. Campbell's paper on "The Origin of Laterite", Trans. Inst. Min. Met., xix, p. 455, 1910, and L. L. Fermor, Geol Mag., 1911, p. 510.

Professor Lacroix next prints in full the tabular classification for laterites and some other surface rocks drawn up by me in 1911.[1] Putting aside for the time my terms *lake laterite*, *lateritoid*, and *lateritite*, he accepts my classification for the group "des latérites proprement dites", with certain reservations necessitated by the characters of the rocks studied.

In the first place he joins together my divisions I (lithomarge, clay, soils, etc.) and II (lateritic rocks) in order to avoid too much detail[2]; and with reference to *quartzose laterites* he thinks it more logical to base the divisions, not on the composition of the rock taken as a whole, but "sur ses éléments néogènes" only. He therefore subdivides laterites carrying quartz, not according to the total tenor in lateritic constituents, but according to their richness in these latter after deducting quartz of primordial origin.[3]

Professor Lacroix then brings forward a much more important modification or rather improvement of my classification, which is based on chemical and not on mineralogical composition. He writes (p. 261)—

"Pour rester dans les principes généraux de la pétrographie, il est donc indispensable de tenir compte de cette composition minéralogique, et *le but principal de ce mémoire* [italics mine] est précisément d'apporter des documents nouveaux à ce point de vue. En conséquence, il faut faire intervenir dans la classification la notion de l'état, cristallin ou colloïdal, dans lequel se trouvent les constituants néogènes (hydrates et silicates)."

Professor Lacroix considers the physical state of the hydroxide of iron as of no importance from the point of view of classification, because the two phases *limonite* (crystalline) and *stilpnosiderite* (colloidal) are rarely completely separated. The hydrates of aluminium, on the other hand, occur either as gibbsite or in the colloidal state.[4]

In my paper already cited (l.c., p. 561) I advanced reasons for avoiding the custom of several authors in regarding *laterite* and *bauxite* as synonymous terms, and suggested the necessity of restricting the term *bauxite* to the varieties of laterite sufficiently rich in Al_2O_3 to be used as ores of aluminium. Even this restriction is not sufficient for Professor Lacroix (p. 262)—

"Puisque la bauxite—au moins celle qui a servi de type et qui constitue tous les gisements français—est caractérisée, ainsi que je l'ai montré depuis longtemps,[5] par l'absence complète de produits cristallisés."

Consequently he qualifies as *gibbsitic*[6] (*gibbsitique*) those laterites

[1] "What is Laterite?" : GEOL. MAG., N.S., Dec. V, Vol. VIII, p. 514, 1911.

[2] There seems to be no good reason why we should exact less precision in naming products with less than 50 per cent of lateritic constituents than with products containing more than 50 per cent. Indeed, greater possibilities of variation amongst the former group necessitate greater precision rather than less.

[3] The undesirability of this course is indicated by consideration of the case of *latérite d'alluvions* noticed in Section IV.

[4] This can be regarded only as a general statement, for examples of the crystalline and colloid forms occurring together are given later in the memoir.

[5] *Min. de la France et de ses colonies*, iii, p. 342, 1901.

[6] Throughout this memoir the author uses the term *hydrargillite* rather than *gibbsite*, but in the adjectival form he prefers *gibbsitic* as being less cumbrous.

containing $Al_2O_3 . 3H_2O$ in the crystalline state, and as *bauxitic* (*bauxitiques*) those containing only colloidal hydrates.[1]

Then, considering the silicates of aluminium found in the laterites of Guinea, Professor Lacroix finds that they exist sometimes as crystalline *kaolinite* and sometimes as *halloysite*, the latter being either more or less crystalline or completely colloidal. He regards it, therefore, as impossible to unite all these products under the term *lithomarge* as proposed by me (l.c., p. 511), because I have suggested that lithomarge is the colloidal variety of kaolinite. This criticism seems to me perfectly valid, but see the next paragraph; the author then summarizes his conclusions in the following scheme of nomenclature, with which I agree in most respects, the mineralogical precision introduced being a very acceptable improvement:—

Divisions basées sur la composition chimique.	Subdivisions basées sur la composition minéralogique.	
		Hydrates d'alumine.
I. Latérites (*Hydrates* $\leqslant$ 90, p. 100).	*Gibbsitiques.*	Cristallisé (hydrargillite).
	Bauxitiques.	Colloïdaux.
II. Latérites silicatées (*Hydrates* = 90 à 50, p. 100).		*Silicates d'alumine.*
III. Kaolins, argiles latéritiques (*Hydrates* < 50, p. 100).	*Kaoliniques.*	Cristallisé (kaolinite).
	Argileuses.	Cryptocrystallins ou colloïdaux.

Each of these types should be qualified by *quartzose* (*quartzifère*) when it contains primary (*ancien*) quartz.

It will be seen that Professor Lacroix uses the term *argileuse* instead of the adjectival equivalent of *halloysite*, with which he identifies the cryptocrystalline and colloidal silicates present. It is interesting to note that other authors have referred the colloidal silicate to the same substance. Thus Bauer[2] regards it as a "Halloysite ähnlichen Aluminiumhydrosilikat"; whilst Mr. E. S. Simpson[3] speaks of "halloysite (amorphous $Al_2O_3 . 2SiO_2 . 2H_2O$)". Halloysite is an indefinite colloidal substance corresponding to the kaolinite formula with additional water, and may itself prove to be the colloidal form of kaolinite, with this additional water in a state of adsorption or solid solution, like a portion of the water of zeolites. Dana in his *System of Mineralogy* divides the old term *lithomarge* between kaolinite and halloysite, retaining it for the firm and compact form of kaolin. If, however, halloysite prove to be related to kaolinite in the way suggested above, then obviously the term lithomarge will be a very convenient one to use for cryptocrystalline and colloidal clays in which the ratio $Al_2O_3 : SiO_2$ is 1 : 2 with a water content varying from that of kaolinite to that of halloysite. I was probably

[1] This nomenclature appears at first sight to be heterogeneous, because gibbsite is a mineral and bauxite a rock (according to Lacroix himself); but this use of *bauxitic* must be taken as analogous to that of *lateritic*, and as referring to the presence of bauxitic constituents. It is doubtful if it will be possible thus to restrict the use of the term bauxite outside the realms of mineralogy and petrology, because for economic purposes we have available no other inclusive term, except *aluminous laterite* or *aluminium-ore*.

[2] *N.J. Min. u. Pet.*, Festband, 1907, p. 87.

[3] "Laterite in Western Australia": Geol. Mag., 1912, p. 400.

wrong in attempting to restrict the term to the colloidal form of kaolinite. The term lithomarge has long been used in the literature of Indian geology for the variegated clays so often underlying the Indian laterites,[1] and has by several decades the priority over halloysite in application to these clays, and it seems therefore desirable to me to retain it in this connexion. Perhaps in the same way as bauxite has been shown to be a rock rather than a mineral, lithomarge must be so regarded. In fact, we might regard lithomarge as related to kaolinite and halloysite in the same way as bauxite is related to the minerals gibbsite and the alumogels (see *infra*).

With this definition of the term lithomarge we may translate and re-arrange Professor Lacroix' improved classification as follows:—

Divisions, based on chemical composition.	Subdivisions, based on mineralogical composition.
Laterites (L.C. $\gtrsim$ 90 per cent)	Gibbsitic laterites. Bauxitic laterites.
Argillaceous laterites (L.C. = 50–90 per cent)	Kaolinic / Lithomargic[2] > gibbsitic laterites. Kaolinic / Lithomargic[2] > bauxitic laterites.
Kaolins, lateritic clays[3] (L.C. < 50 per cent)	Gibbsitic clays. Bauxitic clays.

After closing his introduction with a short *historical résumé* of the previous work on the laterites of Guinea,[4] Professor Lacroix deals in four chapters with the following subjects: (i) The products of

[1] Thus in the publications of the Geological Survey of India it is used by W. T. Blanford as early as 1859; see "Note on the Laterite of Orissa" (Mem. Geol. Surv. Ind., i, p. 286). Blanford clearly distinguishes between the overlying laterite and the underlying lithomarge produced by the decomposition of gneiss. He writes: "The underlying form varies so much in constitution according to the rock from which it is derived, that scarcely any petrological term will include all its varieties. As a rule, however, it is, when derived from gneiss or other felspathic rock, a more or less ferruginous clay varying in purity. To such substances the name *Lithomarge* has frequently been applied, and it seems the most applicable in the present instance, it being understood that all the impure varieties derived from quartzose metamorphic rocks or sandstone are here included in the term." He notes the "apparent passage of Lithomarge into Laterite", but gives a different explanation from that of Professor Lacroix.

[2] By using the term *lithomargic* where Lacroix uses *argileuse*, we have the adjective *argillaceous* or *argileuse*, available as a comprehensive term, including both 'kaolinic' and 'lithomargic'.

[3] I prefer the term *lateritic constituents* (L.C.) to *hydrates*, because, at the surface, laterite sometimes contains the anhydrous mineral *hematite*, developed as a result of dehydration.

[4] In which, by the way, the author overlooks Mr. J. Morrow Campbell's paper entitled "The Origin of Laterite" (Trans. Inst. Min. Met., xix, pp. 432–57, 1910), based largely on observations made in Haute Guinée.

decomposition of the nepheline-syenites, gabbros, diabases, and peridotites (pp. 271–301); (ii) The products of decomposition of the mica-schists, gneisses, and granites (pp. 302–317); (iii) The *latérites d'alluvions* or *lateritoids* (pp. 318–324); (iv) The minerals of laterites.

It will be convenient to notice briefly the contents of chapter iv, and then to give the substance of chapter v in some detail, which summarizes admirably the subject-matter of chapters i to iii, and also gives the author's ideas as to the conditions of formation of laterite.

III. The Minerals of Laterite.

From the mineralogical point of view the most remarkable feature of lateritization is that practically all the minerals so produced are in a state of hydration, either in a colloidal phase (hydrogel) or in a crystalline phase, and most often with the two together. In certain cases it can be shown that crystallization takes place at the expense of the hydrogels, but, as related later, this is not always the case for aluminium hydrate.

Full details are given (p. 326) of the microscopic characters of the crystalline form of aluminium hydrate, namely, *hydrargillite* or *gibbsite*, which is the only crystalline aluminium hydrate found by Professor Lacroix in the laterites of Guinea, there being no evidence for the existence of *diaspore*.

The history of the *colloidal hydrates of aluminium* in laterites cannot be divorced from that of the original *bauxite*, which is only a laterite of a former period found in regions no longer tropical. As long ago as 1901 Professor Lacroix[1] showed that the French bauxites are without exception formed of colloidal hydrates, existing alone or in association with colloidal silicates, demonstrating that bauxite cannot be regarded as a mineral, because it does not correspond with the supposed specific formula of $Al_2O_3 . 2H_2O$; thus in France it has a composition approaching closer to $Al_2O_3 . H_2O$ than to any other, whilst in other regions, as in Arkansas, the composition approaches that of $Al_2O_3 . 3H_2O$. He concludes, therefore, that bauxite must be regarded as a rock composed of various colloidal aluminium hydrates mixed, according to the case, with ferric hydrates, clay, etc. Passing in review the names proposed by various authors for these colloidal hydrates, he rejects the *α-kliachite* and *β-kliachite* of Cornu,[2] the *sporogelite* of M. Kišpatić,[3] and Dittler & Doelter's use of *bauxite*, and their proposed *bauxitite*,[4] adopting the term *alumogel* suggested by M. Pauls.[5] Judging from both his own work and that of M. Arsandaux, Professor Lacroix accepts the existence of one colloidal hydrate with one molecule of water (France and Guinea), and of another with three molecules of water (Guinea and Arkansas).

Dealing with the *ferric hydrates*, he uses the term *limonite* for the crystalline form of $2Fe_2O_3 . 3H_2O$, and revives the old name

[1] *Mineral. de la France et de ses colonies*, iii, p. 342.
[2] *Zeitsch. Chem. industr. Kolloide*, iv, p. 90, 1909 (Lacroix).
[3] *Neues Jahrb.*, Beil. Bd. xxxiv, p. 518, 1912.
[4] *Centralblatt f. Min.*, 1912, pp. 19 and 104; and 1913, p. 193.
[5] *Zeitsch. prakt. Geol.*, xxi, p. 545, 1913 (Lacroix).

stilpnosiderite of Ullmann (1814) for the colloidal form of the same mineral. Details are given of the microscopic characteristics of both these minerals. The red tints often seen in the ferruginous cuirass of laterites are regarded as undoubtedly due to the dissociation of the yellow hydrate under the influence of the sun's rays. But Professor Lacroix regards the product as a mixture of *hematite* with the initial limonite or stilpnosiderite, and not as a special hydrate of formula $2\,Fe_2O_3 . H_2O$, to which the name *hydrohematite* or *turgite* has been attached. He has never detected the presence of *goethite* in the laterites of Guinea, although it has been reported as existing in some of the laterites of that country.

The *silicates of aluminium* exist in two forms, crystalline (*kaolinite*) and *colloïdal*, and of the latter the author detects two varieties, one of them cryptocrystalline, which is regarded as *halloysite*, and the other isotropic, which is supposed to possess a composition near to that of halloysite. From the fact that hydrochloric acid never breaks up more than a very small portion of the clays, he judges that there cannot be present any important quantity of silicates more basic than halloysite, such as allophane. Attempts made in Professor Lacroix's laboratory to repeat the distinction of silicates from hydrates by staining, as announced by Dittler and Doelter, gave such irregular results that they were discontinued.

It has not proved possible to detect mineralogically the presence of *titanium compounds* in laterite. But it is supposed that the portion of the titania of laterites that is soluble in hydrochloric acid exists as orthotitanic acid, $Ti\,O_2 . 2\,H_2O$, whilst the idea of Arsandaux that the portion of the titania of laterites that is soluble only in sulphuric acid, which is the greater part, exists as metatitanic acid, $Ti\,O_2 . H_2O$, is accepted as probable. For these titanic hydrates Lacroix proposes the name *doelterites*, in honour of C. Doelter, who has done so much work on colloid minerals.

It is supposed that the small quantities of chromic oxide detected in some laterites exist as a hydrate of Cr_2O_3, probably in the colloidal form. The only *manganiferous* product in the Guinea laterites consists of a mixture of stilpnosiderite and *psilomelane*, and was found in Los Isles.

IV. The Processes and Products of Lateritization.

In chapter v of his memoir, the author first states the *chemical result* of the formation of laterite, namely, the elimination of the alkalis, alkaline earths, and silica of the original rock, and the persistence of hydrated oxides of aluminium and iron with a little titanic acid, noticing that in different cases the rock is formed in different ways, which lead to important *mineralogical and structural variations* in the final product.

Starting from the intact rock Professor Lacroix has been led to distinguish two superposed zones, the *zone de départ*, which we may translate as the *zone of leaching*, and the *zone de concrétion*. Between the two zones there is perfect continuity, their separation being arbitrary, and necessary only for the sake of a clearer exposition of the problem; the point chosen is that where the original structure of

the rock, still evident in the zone of leaching, ceases to be perceptible. More exactly the lower zone would be spoken of as the zone of maximum departure or leaching.

In the preceding chapters Professor Lacroix has discussed the products of alteration of three distinct groups of rocks, there being distinct types of laterite corresponding to each. These three groups are: (1) nepheline-syenites, gabbros, diabases,[1] and peridotites; (2) micaceous schists and granites; (3) alluvium composed of debris of non-lateritic origin. In this final chapter the author compares the three.

IV (*a*). *Zone of Leaching* (*départ*).

This zone is characterized by the elimination of the greater part of the constituents, the disappearance of which characterizes the phenomenon of lateritization; three cases can be distinguished, marked by the formation of gibbsitic laterites, ferruginous laterites, and bauxitic laterites, respectively.

Gibbsitic Laterites.—In the first case, namely that predominating in the alteration of gabbros, diabases, and nepheline-syenites, the transformation is *abrupt* without transition, the same thin slice showing the contact of the absolutely fresh rock with the portion in which there is no longer any unaltered mineral, and where the leaching of constituents destined to elimination is often almost complete.

In such rocks, the ratios of TiO_2, Fe_2O_3, and Al_2O_3 are at first sensibly the same as in the fresh rock, but as one rises in the section the proportion of iron diminishes very rapidly in consequence of its removal to the higher levels, and later the amount of Al_2O_3 increases with reference to that of the TiO_2.

From the mineralogical point of view the essential feature is the transformation of the felspars into gibbsite, which occupies the body of the destroyed mineral, the composition of the original felspar having no influence on the result; at the same time colloidal products take the place of the other minerals. The transformed rock, with the original structure still visible, is porous and light in weight, with a very characteristic variegated aspect, which to Professor Lacroix suggests *pain d'épices*. This laterite is more or less rich in aluminium silicate, concentrated in the skeletons of the ferro-magnesian minerals, and in the examples represented by analyses Nos. 2, 6, 9, given in Part II, the quantity of silica ranges from 2·21 to 12·67 per cent, corresponding to 5 to 30 per cent of silicate of composition corresponding to the formula $2H_2O . Al_2O_3 . n SiO_2$.[2]

In Los Archipelago where the nepheline-syenites occur, the alteration normally corresponds with that above described, but at

[1] I have retained the term *diabase* throughout this article, although personally I think it an unnecessary term, the word *dolerite* being the more desirable.

[2] In a footnote Lacroix remarks that the essentially kaolinic transformation of a diabase is an exceptional case that he has not himself observed. Such cases occur, however, in India: cf. Mem. Geol. Surv. Ind., xxxvii, p. 376, 1909, where is described the occurrence at Yeruli of a zone of variegated argillaceous material intervening between the underlying basaltic rock and overlying laterite.

certain points in these islands it has locally pursued a totally different course, with formation of a plastic clay (see analysis No. 4, Part II). The association of these two different types of alteration is so intimate that Professor Lacroix has no explanation to offer of their coexistence at the same point (p. 281). It impels the question whether, in the normal case, gibbsite, instead of being the first secondary product formed from the felspars, may not itself have been derived from the destruction of an aluminium silicate. Judging from the examination of a considerable number of specimens in which the type of transformation is always the same, Professor Lacroix answers this question in the negative, thinking it likely that the decomposition has been from the beginning a hydrolysis of the original silicates.[1]

Ferruginous Laterites.—Ferruginous laterites in the zone of leaching result from the alteration of peridotites, owing to the poverty of these rocks in aluminiferous silicates. The ferro-magnesian silicates decompose in the same manner as in the gabbros, furnishing colloidal ferric products, containing some alumina (see analysis No. 9, Part II). The rock is porous, ochreous, light, and friable.

Kaolinic and Argillaceous Decomposition.—This, the third form of alteration in the zone of leaching, characterizes the mica-schists, gneisses, and granites. It is clearly distinguishable from the first case, because, instead of an abrupt alteration without intermediate phase, there is a *progressive change*, so gradual and extending to such a depth that the unaltered rock is seldom seen. In the mica-schists of Fatoya, borings pushed to a depth of 60 metres have not reached the fresh rock, probably because the vertical disposition of the schists has facilitated their alteration. Consequently, in contrast to the rocks considered above, in which the original structure persists for only a few metres above the original fresh rock, the *initial structure*

[1] Mr. E. S. Simpson (GEOL. MAG., 1912, p. 401) has criticized adversely my postulation (GEOL. MAG., 1911, p. 459) of two distinct modes of decomposition of rocks resulting respectively in the formation of clay and laterite, apparently because in Western Australia primary laterite is always found to overlie an almost pure pipeclay and this in turn a crystalline rock. From the work of Lacroix it is seen that the felspar in a crystalline rock, such as nepheline-syenite, may alter *directly into gibbsite* or *directly into a hydrous aluminium silicate*. When the latter forms, a chemical change may cease at this stage, as in Los Archipelago, or it may proceed further, as in the case of the mica-schists noticed on a later page in this paper. With reference to Mr. Simpson's comparison of lateritization with the formation of saline efflorescences, Lacroix' work indicates a marked distinction. A saline efflorescence is deposited *on* the surface of the ground; the constituents of a lateritic crust, on the other hand, are partly *residual* (although recrystallized), formed approximately in their present place from the once fresh primary rock, at the time when the zone of leaching was at this level; and have partly been brought up from the zone of leaching and added to the residual portions: in any case these constituents were deposited *inside* the crust and not *on* the surface, except perhaps to a very minor degree. In the following paragraph Mr. Simpson gives a curious definition of a *replacement of a rock*, namely, "a deposit accumulating in the actual space originally occupied by the solid rock which has yielded the materials which compose the laterite." Surely the essential feature of replacement is that the replacing mineral has been brought from elsewhere, and has been deposited in the place of another mineral removed in solution.

is here preserved through a very great thickness of altered rock; but the degree of cohesion of the rock is profoundly modified, the rock being unctuous to the touch and friable when dry. The micas are progressively deprived of their alkalis concurrently with the fixation of a larger and larger quantity of water (see analysis on p. 306 of Lacroix' memoir). From this results kaolinite or colloidal silicates of aluminium, mixed with a greater and greater quantity of aluminium hydrate. This mode of alteration also characterizes certain granites and gneisses in Guinea. None of these products of alteration in the zone of leaching would be designated laterite; they are fundamentally *kaolins* or *clays*, passing upwards into *lateritic clays*.

The type of alteration is not characteristic of a given rock.—Judging from the results given above, one might think that in the Tropics the mode of alteration of the rocks is always determined by the mineralogical and chemical composition of the original rock. Such a generalization would be inexact, as is shown by observations made in Madagascar, where the gabbros, diabases, and nepheline-syenites behave as in Guinea, but where the granites and gneisses give rise not only to a great development of argillaceous alteration products, as in Guinea, but also in places give rise to gibbsitic laterites, often quite free from iron.

(To be continued.)

REVIEWS.

I.—Water Reptiles of the Past and Present. By Professor S. W. Williston. pp. 251, with 131 text-figures. Published by the University of Chicago Press: Agents in Great Britain, the Cambridge University Press, Fetter Lane, London. Price 12*s*. net.

IN this volume Professor Williston has endeavoured to give a popular account of the various groups of reptiles which have become more or less adapted to an aquatic life, and to a great extent he has succeeded in this difficult task. At the same time it is not easy to tell how far a work of this kind will appeal to the general reader, since much that is highly technical and unfamiliar necessarily remains. In any case, the book is a valuable one because it brings together in a compact form a large amount of information hitherto widely scattered and often not easily accessible.

In the earlier chapters the author gives a general account of the mode of occurrence of fossil reptiles, of their classification and their osteology. The chapter dealing with the last-mentioned subject might perhaps have been extended with advantage, and, indeed, if so good an authority as Professor Williston would publish a volume on the osteology of the class, it would fill one of the most notable gaps in palæontological literature. The subject essentially is one for the palæontologist, since in perhaps no other group of the Vertebrata are the fossil forms of such preponderating importance. This will be understood when it is realized that out of the fifteen

orders into which the Reptilia may be divided no less than eleven became extinct before the end of the Secondary Period.

In the succeeding chapters an account is given of the distribution in time and space of the extinct forms, together with a very clear account of the different modifications undergone in the various groups in the course of their adaptation to an aquatic mode of life: the chapter dealing with this subject is perhaps the most generally interesting in the book.

The remainder of the volume is occupied by a series of chapters on the different orders in which some or all of the members have adopted an aquatic life. These orders are: the Sauropterygia; the Anomodontia, among which *Lystrosaurus* seems to have been at least semi-aquatic; the Ichthyosauria; the Proganosauria; the Protorosauria; the Squamata; the Thalattosauria; the Rhynchocephalia; the Parasuchia; the Crocodilia; and, finally, the Chelonia. The author, naturally, where possible refers to American types to illustrate his points, and most of the illustrations, which include numerous restorations, are likewise of American species.

This book should certainly be read by all who are interested in reptiles, living or extinct, for, although especially devoted to aquatic types, it gives a good idea of the immense diversity of form that has been attained by members of the class.

C. W. A.

II.—Reptiles and Batrachians. By E. G. Boulenger, F.Z.S. pp. 278, with 79 photographic plates (one coloured) and 25 text-figures. London: Dent & Sons, Ltd. Price 16*s.* net.

ALTHOUGH this book refers almost exclusively to living reptiles and batrachians, and more especially to their habits, nevertheless it is of considerable importance to the palæontologist, since a knowledge of the habits of recent forms is often valuable in giving suggestions for the explanation of peculiarities in the structure of extinct types. Mr. E. G. Boulenger, as Curator of the Lower Vertebrates at the Gardens of the Zoological Society, has had exceptionally good opportunities for observing the habits of the animals in question, and he has made use of them in this volume. The illustrations are for the most part a series of fine photographs, mostly taken from the life of Mr. W. S. Berridge, F.Z.S., and excellently reproduced.

III.—Mineral Resources of the United States, Calendar Year 1913.

THIS valuable work is now issued by the Geological Survey in instalments, chapter by chapter, in order to secure promptitude of publication. It is divided into two parts, dealing respectively with Metals and Non-metals. The pagination of the chapters in each is consecutive, and title-pages, tables of contents, and indices are supplied to those wishing to assemble and bind together the component chapters. Although compiled from the point of view of the United States, the work appeals to all interested in the

commercial application of minerals, and contains much valuable information on the mode of occurrence, the treatment of the ores, and the uses to which the products are put. Statistics are given of the production of the various minerals and the exports and imports in the case of the United States, and often the figures for other countries are added.

In the chapter on Bauxite and Aluminium the Serpek process for fixing nitrogen by means of bauxite is described. The reaction is of the type $Al_2O_3 + 3C + 2N = 2AlN + 3CO$, the aluminium nitride yielding with water ammonia and alumina, the latter in a very pure form. In another chapter an alloy of nickel, chromium, and copper is described which withstands the solvent action of strong acids. The chapter on the recovery of secondary metals reveals the remarkable dimensions which the treatment of scrap metal has reached, nearly seventy-three million dollars worth of metal being recovered in the United States, and that exclusive of gold, silver, platinum, and iron. A new mica product, which has been put on the market under the name 'micarta' by the Westinghouse Electrical and Manufacturing Company, is a tan-coloured, hard, and homogeneous material which can be sawn, milled, and threaded, and does not warp to any appreciable extent. One grade of it, 'bakelite micarta,' is infusible, and insoluble in nearly all the ordinary solvents. We notice on turning over the pages what a large variety of minerals are used in the decorative arts, the textile industry, and paper manufacture.

IV.—Middle Triassic Marine Invertebrate Faunas of North America. By J. Perrin Smith. Professional Paper No. 83 of the United States Geological Survey. 4to; pp. 148 and 99 plates. 1914.

MR. J. PERRIN SMITH'S memoir on the above is a handsome and well-illustrated survey of three orders of Cephalopoda (Ammonoidea, Belemnoidea, and Nautiloidea) and some genera of Lamellibranchia, Brachiopoda, and Crinoidea. The work forms the second part of a series of three volumes on the marine invertebrate faunas of the Lower, Middle, and Upper Trias of North America which continues and supplements a previously published work by the same author, consisting of a synoptical introduction to the whole fauna. Professor Alpheus Hyatt and Mr. Smith originally proposed to produce a joint monograph on this subject, but owing to Professor Hyatt's advanced age the project was not proceeded with, and ultimately Mr. Smith's introduction, in the preparation of which he had Professor Hyatt's assistance, was substituted, appearing as Professional Paper No. 40 of the Survey.

The present work will be mainly interesting to the general student (apart from the specialist) for its excellent summary of the relationship of the fauna of the Middle Triassic seas of North America to those of the Eastern Hemisphere. Mr. Smith's conclusion on this question is that the kinship between the American and Mediterranean faunas is closer than that between the American and Asiatic. In addition

to the strictly systematic portion in which two new genera and many new species are described there is a short and vivid description of the geography of Triassic North America, and a table giving the interregional correlation of the Triassic areas. The work is copiously illustrated with ninety-nine quarto plates.

V.—Fauna of the Spiti Shales.

THE report upon the fauna of the Spiti Shales is continued in *Palæontologia Indica* by pt. ii of vol. iv (4to, pp. 397–456, pls. xciv–c), in which Dr. Karl Holdhaus contributes a study (translated by Mr. E. W. Vredenburg) of the Lamellibranchia and Gastropoda.

Dr. Holdhaus describes a new and interesting genus, *Cosmomya*, the precise systematic position of which is doubtful, and about twenty new species of Lamellibranchia. The Gastropoda from the Shales are poorly represented, a new species of *Pleurotomaria*, a poorly preserved *Cerithium*, and the cast of an indeterminable form being the only material available for study. Careful and exhaustive descriptions of the new species are given, and Dr. Holdhaus enters a plea for full and correct descriptions in palæontological literature.

As the author points out, the Lamellibranchia do not possess the same importance from the stratigraphical point of view as other groups of animals, and in this case they do nothing more than endorse the conclusions based on a study of the Ammonites. A few forms point to Upper Jurassic age for the Shales, but on the whole the Lamellibranchia supply no precise indications of age. Dr. Holdhaus treats the faunistic relations of the group with caution. He restricts himself to inferring a possible connexion with the Jurassic faunas of Europe, but points out the occurrence of forms which may indicate other affinities, for instance with Somaliland and Arabia. He also ventures to suggest a close connexion with the Jurassic of Kachh, though he admits that the Lamellibranch fauna of the latter is as yet imperfectly known. On the whole, the Spiti Shales Lamellibranchia appear to be eminently specialized, and, with due qualifications, Dr. Holdhaus states that he is unable to point to a single species (with the exception of some species of *Astarte* with possible Kachh relationships) as truly identical with the fossils of other Jurassic regions.

VI.—Crinoids and Dolomite. By F. W. Clarke and W. C. Wheeler.

MESSRS. F. W. CLARKE and W. C. Wheeler (United States Geological Survey, Professional Paper 90–D; June 16, 1914) have followed up observations made by H. W. Nichols (1906) and A. H. Clark (1911), and have analysed the skeletons of specimens belonging to nineteen genera of recent crinoids. As in the previous cases, all contained magnesium carbonate in proportions varying from 7·28 to 12·69 per cent. The available data show a general increase of this constituent with increase of temperature in the water, but the reason for this relation is not clear. The skeletons

of ten fossil crinoids, ranging from Lower Ordovician to Eocene, were also examined, but, with one exception, showed a very small percentage (·8 to 2·56) of magnesium carbonate. The alteration is ascribed mainly to infiltration by calcium carbonate and other constituents, which would naturally lower the proportion of magnesium carbonate. The original suggestion, therefore, that crinoids might play an important part in the formation of magnesian limestones is far from being supported. Nor is it supported by the sole exception, for this was a stem of the common Lily Encrinite from the Muschelkalk; and the reason that this had no less than 20·23 per cent of magnesium carbonate is presumably that it came from one of the many Muschelkalk limestones that have been dolomitized. Even so the proportion of magnesium carbonate does not come near that which obtains in true dolomite.

VII.—Professor E. S. Morse on an Early Stage of *Acmæa*.

PROFESSOR EDWARD S. MORSE'S paper (Proc. Boston Society of Natural History, February, 1910) on "An Early Stage of *Acmæa*", though delayed in coming into our hands, deserves even a late appreciation. Contributions to our knowledge of the phylogeny of the Mollusca are exceedingly desirable, and we wish students of this phylum would spare more time from systematic conchology to the study of such problems as Mr. Morse deals with in his paper. The author, after a study of two species of *Acmæa*, in which (in one at least) no trace of a coiled Nautiloid apex was found in the embryonic stage (though such a coiled apex has been found in the early stages of other Docoglossa), proceeds to review some of the evidence (palæontological, embryological, and anatomical) that suggests that the Docoglossa are actually primitive Gastropoda. It is plain, of course, that all the members of the sub-order (*Lepeta*, *Pilidium*, *Helcion*, etc.) must be examined before we attempt to formulate any final statement as to the evolutionary status of the Docoglossa, and in the meantime such evidence as Mr. Morse is able to produce is most valuable, if not actually sufficient to upset the belief that the Docoglossa are not entirely primitive in their structure.

VIII.—Brief Notices.

1. In a paper recently published in the Smithsonian Miscellaneous Collections (vol. lx, No. 21) J. W. Gedley records the occurrence of a bone of a camel associated with remains of the mammoth and bison, from a locality in the Yukon Territory, Alaska, some distance within the Arctic Circle. Although, as is well known, the Bactrian Camel can endure extreme cold, no remains of any member of this group have hitherto been found nearly so far north.

2. Chalk of Gingin, Western Australia.—Mr. R. Etheridge has issued as Bulletin No. 55 (1913) of the Geological Survey of Western Australia a description of the fossils of the Gingin Chalk. The fauna shows a striking similarity to the uppermost White Chalk of England, with *Magas* and *Trigonosemus*. In Bulletins Nos. 36 (1910)

and 50 (1912) the stratigraphy of this deposit was dealt with by Messrs. Glauert, Maitland, and Montgomery.

3. Cambrian Stratigraphy in the North American Cordillera.—Mr. L. D. Burling discusses the *Albertella* fauna, and shows that it is unassociated with *Olenellus*, and consists of forms either typical of Middle Cambrian or confined to the *Albertella* fauna, as species of unknown or connecting affinities. The lower Middle Cambrian boundary has now been drawn at the base of such horizons as the one containing the *Albertella* fauna. (Mus. Bull. 2, Dept. of Mines, Canada, 1914.)

4. Geology of Long Island.—An elaborate and detailed description of the geology of Long Island is provided by M. L. Fuller as Professional Paper 82, Department of Interior, United States Geological Survey, 1914. The paper is fully illustrated by sections and topographic maps. As there is a large amount of Quaternary and Glacial deposit on the island, the work may be studied with profit by many English geologists quite apart from its general interests in a stratigraphical direction.

5. Transportation of Debris by Running Water.—G. K. Gilbert and E. C. Murphy, in dealing with the subject of transportation by running water, discuss the apparatus employed, adjustment of observations, relation of capacity to slope, relation of capacity to form ratio, of capacity to discharge, to fineness of debris, to velocity, to depth; experiments with mixed grades, with crooked channels, flume traction, natural streams, rhythm. (Professional Paper 86, Department of Interior, United States Geological Survey, 1914.)

6. Note on the Temperature in the Deep Boring at Findlay, Ohio. By John Johnson. Amer. Journ. Science, vol. xxxvi, pp. 131, 1913.

The temperatures of the borehole were measured by maximum reading thermometers, three thermometers in a copper cage being used for each measurement. The total depth of the boring was 2,980 feet, and throughout the lower 2,000 feet the gradient was determined to be practically uniform, viz. 0·41° C. (0·74° F.) per 100 feet. Gas flows through the rocks down to a depth of 770 feet, and, as might be expected, the expansion of this gas when it reaches the borehole results in cooling. Consequently the temperatures measured down to that depth are uniformly too low, being those of the expanding gas, and not those of the adjacent rocks.

7. The Grand Gulch Mining Region, Mohave County, Arizona. By James M. Hill. United States Geological Survey, Bulletin 580–D. pp. 58. Washington, 1914.

The copper-ore bodies occur around the side of a vertical mass of sedimentary rocks lying within a series of stratified rocks. The original sulphides have been largely converted into carbonates. The metals appear to have been brought to their present position by generally downward moving waters, which were probably cold, since no hydrothermal alteration of the wall rocks in the vicinity was noticed.

REPORTS AND PROCEEDINGS.

I.—Zoological Society of London.

November 24, 1914.—Professor E. A. Minchin, M.A., F.R.S., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

Dr. R. Broom, C.M.Z.S., exhibited the skull of a new type of Thecodont Reptile from the Upper Permian beds of South Africa, and a number of skulls of *Trichosurus vulpecula*, *Phascolarctus cinereus*, *Chrysochloris hottentota*, and *C. asiatica*, illustrating dental variations.

Dr. C. W. Andrews, F.R.S., F.Z.S., communicated three papers by Mr. D. M. S. Watson.

The first paper contained the description of a new reptile from the Permian of the Cape Province, South Africa, which Mr. Watson regards as derived from a Cotylosaurian ancestor and as perhaps related to *Arœoscelis* and the modern lizards. A new genus is founded for the reception of the so-called '*Proterosaurus huxleyi*'.

In the second paper the origin of the Chelonia is discussed, and a number of reasons given for supposing that they may be descended from some such form as *Eunotosaurus africanus*, Seeley.

In the third paper Mr. Watson describes the skulls of *Bauria*, *Microgomphodon*, and *Sesamodon*, and discusses the relation of the group with the Cynognathids. He also describes a new skull of *Lycosuchus*, in which both the prevomers and vomer are present.

II.—Geologists' Association.

On *December* 4, 1914, at University College, Gower Street, W.C., the President (George W. Young, F.G.S., F.Z.S.) in the chair, the following lecture was delivered :—

"The Fossil Flora of the Pettycur Limestone." By W. T. Gordon, M.A., D.Sc., F.R.S.E.

Several localities are known where rocks of Lower Carboniferous age have yielded petrified plant remains, but nowhere has such a variety of types been obtained as at Pettycur, near Burntisland. Here the sediments are of Calciferous Sandstone age, but the great bulk of the rocks are of igneous origin, and the plant petrifactions, preserved in lime or silica, occur in the igneous rocks either separately or in masses.

The rocks have been very vesicular, show pillow structure, and are much decomposed. Round the petrified masses ashy material is always present, and it is possible that we have a set of mud lavas into which later injections of fresh material have been forced.

The decomposition of the ashes—in which there were numerous limestone fragments—gave rise to solutions of calcareous and siliceous material by which vegetable fragments enveloped in the ashes became petrified. Volcanic ashes here, and probably in other districts also, offer opportunities for palæobotanical research of great importance.

III.—Geological Society of London.

December 2, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Age and Character of the Shippea Hill Man." By Professor T. McKenny Hughes, M.A., F.R.S., F.G.S.

The author first gives a general description of the skeleton, and of the position and circumstances in which it was found. He then discusses the mode of formation of the deposit in which the remains occurred, and the limits within which, from that point of view, we may speculate as to their age. He considers that the Pleistocene deposits of the Fenland were laid down in a gradually depressed river-basin behind a breached seaward barrier, and gives examples from adjoining areas of similar geographical conditions.

Gravels of the age of *Elephas antiquus* and *Rhinoceros merckii*, as well as gravels of the age of *Elephas primigenius* and *Rhinoceros tichorhinus*, occur within the Fenland; but they are easily distinguished from the gravels which are sometimes associated with the peat and clay, and pass under them. The fauna also of the peat and clay deposits is quite different. This area was gradually depressed, and the conflict between the upland waters and the sea went on through both the ages just referred to, as shown by the earlier *Corbicula* Bed of March and the newer Cockle Bed of Littleport.

In an embayed part of the Fen, close behind the island known as Shippea Hill, the skeleton was found in the peat, a few inches above the clay which the author considers to be the equivalent of this Littleport Cockle Bed. When first dug out the skull was in fragments, and the calotte, with its prominent brow-ridges, suggested to many a greater affinity to the Neanderthal type, and a greater antiquity than appeared probable when the rest of the cranium was added to it.

In a preliminary notice published by the author, he claimed that it could not be older than Neolithic, and suggested that it might be even as late as the time of the monks of Ely, who had a retreat on the island close by.

The author, in reply, said that they had of course been on the look-out for evidence of interment; but, as he had explained in the paper, there was none.

The comparison of the conditions of the Wash with those of the Baltic showed that the Wash was an area of depression during those later ages of which he was speaking; whereas, in later times, the Baltic was an area of elevation by which it was gradually cut off from the open sea, so that the excess of fresh water poured into it had made the eastern water now so little salt that he had seen cows drinking on the shores of the Gulf of Finland. As to the statement that the depression of the area of the Wash was entirely pre-Roman, he did not himself know of any satisfactory evidence leading to that conclusion; but that the Romans did something towards the reclamation of the Fens was suggested by the Roman remains along

the bank running through the peat from Reach to Upware, and by the evidence offered by Lord Peckover as to the Roman work on the seabanks north of Wisbech. He did not think that it could be maintained that the Fenland was ever uninhabitable or uninhabited, although, until the marshy and peaty portions had been reclaimed, it was only the gravel-spurs and islands that were occupied. Crowland, for instance, was built on a gravel-bed.

2. "On a Bone Implement from Piltdown (Sussex)." By Charles Dawson, F.S.A., F.G.S., and A. Smith Woodward, LL.D., F.R.S., Pres.G.S.

During the past season the authors have continued excavations in the Piltdown gravel round the edge of the area previously explored. Rolled fragments of highly mineralized teeth of *Rhinoceros* and *Mastodon* were again found, but no human remains were met with. The most important discovery was a large bone implement, which is now described. This specimen was found in dark vegetable soil beneath the hedge which bounds the gravel-pit, not far from the spoil-heap whence the right parietal bone of the Piltdown skull was obtained two years ago. On being washed away the soil left no stain on the bone, which was covered with firmly adherent yellow clay, closely similar to that of the flint-bearing layer at the bottom of the gravel. The bone itself is highly mineralized, and agrees exactly in appearance with some small fragments of bone which the authors discovered actually in place in the clay just mentioned. There can be no doubt therefore, that the implement was found by the workmen when they were digging gravel from the adjacent hole, and was thrown away by them with the other useless debris. It is a stout and nearly straight narrow flake of bone, 41 cm. long, and varying from 9 to 10 cm. in width, with the thicker end artificially pointed, the thinner end artificially rounded. It appears to be a longitudinal strip flaked from a limb-bone by a blow at the thicker end, in the same way as flint implements were flaked from their original cores. Direct comparison suggests that it was taken from a Proboscidean femur as large as that of *Elephas meridionalis*. In microscopic structure it agrees with Proboscidean bone. The two ends of the implement are shaped entirely by cutting, and bear no marks of grinding or rubbing. Most of the cut facettes are small, and many of them suggest that they were made by some primitive tool, presumably a flint. The rounded end seems to have been trimmed for comfortable handling. The thick pointed (or, rather, keeled) end does not show any signs of battering or scratching by use. Just above the pointed end one lateral edge of the bone is marked by a large smooth groove running across from the inner to the outer face of the bone. It seems to have been originally a perforation from which the outer wall has been accidentally broken away. Within it on the inner face is the beginning of a second similar perforation, as if an attempt had been made to repair the damage. The authors conclude that the implement is unique, and are unable to explain its specific use.

CORRESPONDENCE.

PRE-PALÆOLITHIC FLINT IMPLEMENTS.

Sir,—Mr. Hazzledine Warren and I evidently differ very widely on the question of man's antiquity. He expresses the opinion that the more our knowledge grows of the various ways in which a flint fractures, the less faith will archæologists have in the human origin of pre-Palæolithic flints; while I believe with equal steadfastness that the very reverse will be the case. Now, I am sure Mr. Warren is an earnest seeker after truth, and I hope I am also. Yet we disagree absolutely as to the correct interpretation of the evidence bearing upon this matter which has been collected, and it seems to me that it would be as well to attempt to put our respective opinions to a somewhat stringent test, and to ascertain, in fact, which of us knows most about flint fracture. Such a test will naturally remove this controversy from the realm of theoretical discussion to that of practical demonstration; but it is necessary to do this if any real advance is to be made in our knowledge of the subject, and I therefore submit the following proposals to Mr. Warren, which I hope he will seriously consider, and make known through the medium of your journal whether he accepts them or not. I take it Mr. Warren believes that the edge-trimmed flints, found chiefly in the Plateau Drift of Kent and usually described as 'eoliths', have been produced by some form of pressure. I, on the other hand, regard these specimens as having been flaked by blows, and I also believe that it is possible to differentiate between pressure and percussion flaking. I therefore propose that Mr. Warren selects forty flint pebbles, and that he flakes twenty of them by means of a hammer-stone of some sort into the usual hollow-scraper type of 'eolith', and subjects the remaining twenty to any form of pressure he likes which will also produce similar forms. Having done this, I would suggest he puts distinguishing and faithful marks upon each, by means of which he will know which have been flaked by pressure and which by blows, and that these specimens be then submitted to my examination at a meeting of some scientific body such as the Geological Society. If this is done, and if a good light is provided, I will then and there examine the forty flints and state which I consider have been flaked by pressure and which by blows, and further, if I do not judge 75 per cent of them correctly, I will then and there admit that my claim to be able to differentiate between the two forms of fracture is not substantiated.

It will be noticed I refer only to the simple edge-trimmed tabular flints first discovered by Mr. Benjamin Harrison, of Kent, and make no mention of the much more elaborately flaked specimens which have been found beneath the Red Crag of Suffolk. These form an entirely different subject of inquiry, and can be dealt with when the easier question of the 'eoliths' is settled. But if it turns out that I am vanquished in the contest I suggest, my views regarding the 'humanity' of the sub-Crag flints will naturally lose prestige, while if I should happen to be the victor it will show I am in possession of

certain knowledge which enables me to say with a high degree of certainty whether a flint has been fractured by blows or by pressure, and that in consequence these views have received definite and solid support. I hope Mr. Warren will agree to accept these proposals, and that the result of my examination of the flints to be fractured shall appear in the pages of this journal.

J. Reid Moir.

CONCERNING LATERITE IN GUIANA.

Sir,—In 1911 I contributed an article to this Magazine entitled "What is Laterite?" which arose from a discussion in these pages, initiated by a review of Professor J. B. Harrison's work, *The Geology of the Goldfields of British Guiana* (1908). In this article I put forward a tentative system of classification of lateritic products, by which I proposed to test the use of the word *laterite* by certain authors. Amongst the work criticized was a paper by Professor Harrison entitled "The Residual Earths of British Guiana commonly termed 'Laterite'", in the Geol. Mag., 1910, pp. 439–52, 488–95, 553–62, and also that of Du Bois entitled "Beitrag zur Kenntniss der Surinamischen Laterite", published in *Tschermak's Mittheilungen*, 1903. I drew the conclusion (loc. cit., pp. 563–4), judging from the work of Harrison and Du Bois, that the term has been too widely used in the Guianas.

Last year I received from Professor Harrison a letter to which, owing to the distractions of furlough and travel, I have not been able, hitherto, to give the careful consideration it deserves. From Professor Harrison's letter it appears that my conclusion given above is too sweeping, and therefore in justice to Professor Harrison I am making this communication.

I cannot do better than quote a section of this letter:—

"With reference to the various points in my published papers noticed by you I may mention that I had not an opportunity of correcting the proofs, and hence there are in the papers some wordings which would have been amended if I had had such an opportunity; the copies I send you have been so corrected. Among them is the heading to Table I, on p. 441.[1] The object of that table is to illustrate the somewhat diverse nature of *sedentary* soils covering areas of aluminous laterite. This is clearly seen by reference to the last sentence of p. 440. Unfortunately, in copying the analyses, the word 'Ironstone' over the word 'gravel' in the fourth column of the table was omitted.

"During 1897–1902 I analysed several specimens of 'ironstone gravels' and found them to contain from 80 to as much as 95 per cent of iron and aluminum hydrates, principally the former. These bring up the lateritic constituents of some of these soils very materially, for instance:—

	$Fe_2O_3 + Al_2O_3$
Hiamaraka Hill soil	72 per cent
Arakaka	56 ,,
Konawaruk Road, 12 miles	33 ,,
,, ,, 14½ ,,	55 ,,
Woopu	72 ,,
Issorora	65 ,,
Malali	62 ,,

[1] Which Professor Harrison corrects from "Analyses of Laterite Soils" to "Analyses of Soils on Laterite".